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ACTA ORTHOPAEDICA SCANDINAVICA

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Editor

ZINC CONTENT OF HUMAN CANCELLOUS BONE

E M ALHAVA, H OLLKONEN, J PUHTINEN & V-M NOKSO-KOIVISTO

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The zinc content of cancellous bone from the iliac crest was determined by the X-ray fluorescence technique in an autopsy series of 20 women and 66 men. The bone zinc content was statistically related to age, but there was a large variation. It reached a maximum value in the fifth decade and thereafter decreased with age in both sexes. Men with a chronic disease had a lower zinc content than those who had died suddenly. There was a significant correlation between the zinc content and the bone strength in women ($p < 0.01$) and in men ($p < 0.05$). Zinc is thought to play a part in osteoporosis.

Key words: zinc, bone and bones, osteoporosis, bone strength.

Accepted 20. 1. 76

Zinc is one of the most abundant of the essential trace elements in the human body. It has been reported to exert an effect upon enzymes and enzymatic function (Mikac-Devic 1970), protein synthesis (Lipjokka & Lieberman 1964), carbohydrate metabolism (Mikac-Devic 1970) and bone formation (Haumont & McLean 1966). Quite a lot is known about the zinc content of the skeleton, but we know little about any changes in osteoporosis or bone fragility (Aitken 1976).

The purpose of the present investigation was to study the zinc content in the cancellous bone of the iliac crest with regard to age, sex, disease, bone strength and mineral density.

sex distribution is shown in Figure 1. Fourteen of the women and 45 of the men had died suddenly from acute coronary artery disease or accidents. The remaining 14 women and 21 men had died from chronic immobilizing diseases.

METHODS

a) *Macerated specimen*

The sample was placed in a 5 per cent solution of sodium hypochlorite until the soft organic tissues were destroyed. It was then washed carefully with water, and then incubated at 20°C in 5 per cent sodium bicarbonate for 48 hours and re washed with water. The sample was then left in 5 per cent hydrogen peroxide for 48 hours and washed again. Residual fat was removed from the dry sample with xylene (72 hours).

MATERIAL

Two bone specimens were taken post mortem from the anterior iliac crests of 23 women and 66 men, both urban and rural dwellers in the central hospital district of Kuopio. One of the specimens was macerated and the other was fixed in 40 per cent ethyl alcohol. The age and

area of the iliac crest was measured by the ^{239}Pu excited semiconductor detector X-ray fluorescence analysis (Patomaki & Ollkonen 1974, Ollkonen et al 1977). The area of the zinc K α X-ray peak (8.6 keV) was calibrated by adding different amounts of internal standard (ZnCl_2) to a series of ten samples. The reproducibility of the method was tested in ten samples from the

bone material containing 50 $\mu\text{g/g}$ of zinc. The coefficient of variation was 35 per cent.

b) Fixed specimen

A strain-transducer (Nokso-Koivisto et al 1976) was used for measurements of the compressive strength of trabecular bone. The diameter of the measuring pin was 3.0 mm. The result was expressed as the mean of three measuring values obtained at different locations on the cut surface of the specimen.

Bone-mineral density was determined using a modification of the gamma ray attenuation method presented by Karjalainen (1973).

RESULTS

The zinc content of dry fat-free cancellous bone showed large distributions in both sexes as a function of age (Figure 1). The second-degree regression curves fitted to the distributions show that zinc concentration reaches its statistical maximum in the fifth decade in both sexes and thereafter decreases with age. Males with a chronic disease had a significantly lower zinc content than those who died suddenly ($p < 0.01$, *t*-test).

Both the bone strength and mineral-density distributions showed a significant ($p < 0.01$) decrease with age after the age of 30 in both sexes.

Bone strength correlated highly significantly with the mineral density of cancellous bone both in females ($r = 0.59$, $p < 0.001$) and in males ($r = 0.65$, $p < 0.001$).

Correlations of the zinc content with bone-compressive strength and age are summarized in Table 1. In the statistical analysis of the results for a linear correlation with the zinc concentration, bone strength and age, bones under 30 years of age, that is, those in the ascending part of the parabolic zinc distribution, were excluded. The zinc concentration correlated significantly with the bone strength in females and in the whole male group. The correlation was also significant for the male cases of sudden death, but not for deaths due to chronic disease. The

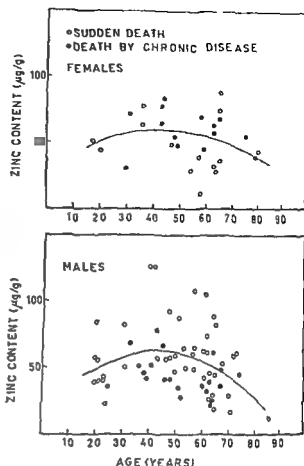


Figure 1. Distribution of the zinc content of dry fat free cancellous bone according to age.

Table 1. Correlations of the zinc content of cancellous bone with strength and age in groups ≥ 30 years of age.

	Strength	Age
Females (Total 26)	$r = 0.48$ $p < 0.01$	$r = -0.37$ $p < 0.05$
Males (Total, 57)	$r = 0.33$ $p < 0.05$	$r = -0.34$ $p < 0.01$
Males (Sudden deaths 36)	$r = 0.40$ $p < 0.01$	$r = 0.47$ $p < 0.01$
Males (Deaths from chronic disease, 21)	$r = 0.23$ $\backslash \backslash$	$r = -0.36$ $\backslash \backslash$

$\backslash \backslash$ = not significant

zinc content was significantly related to age in females, in the whole male group and male sudden deaths. On the other hand, males with chronic disease had a

zinc content which was not correlated with their age

DISCUSSION

There is loss of bone mineral in chronic diseases which cause physical inactivity. We assume that our rough division of patients into cases of sudden death and chronic immobilizing diseases would separate osteoporotics from those with a normal mineral status. We used the area of iliac cancellous bone for the present study because metabolic changes are more detectable in trabecular than in cortical bone (Frost 1966). Moreover, in clinical work histopathological studies are usually performed from the iliac bone biopsies. Our strain transducer is also constructed to measure the trabecular bone strength. We made the measurements of the cancellous bone area on the cut surface of iliac bone as far as possible from the periosteal borders. The determination of zinc by λ ray fluorescence is highly sensitive but we have not found any reports on the use of this method for the measurement of bone zinc. The zinc values obtained in this work were between the values previously reported for bone ash and fresh weight (Calhoun et al 1974). Close comparisons are difficult because of different pre-treatment procedures.

There are a number of studies of the zinc concentration in human bone (Vasbaum et al 1965; Becker et al 1968; Strichow & Kneip 1969; Sjogard & Becker 1970; McBean et al 1972; Aitken 1976). Becker's group studied the trace elements of archaeological and modern bones and reported that the zinc content was the same in old and newer bones. McBean et al (1972) studied 30 adult subjects at necropsy. They divided the group into two categories: accidental deaths (controls) and deaths due to disease. Analysis of the bone did not reveal any statistically

significant difference between the mean zinc concentrations in these two groups. In our study, men with a chronic disease had a lower zinc content than those who had died suddenly. Patients with diabetes, malignant disease or coronary artery disease did not differ from the others in their bone-zinc content. This may be due to the relatively small number of patients in these groups.

Aitken (1976) showed a progressive increase with age in the bone zinc content relative to calcium. We found an increase in our study up to the age of about 40, and thereafter a decrease in the zinc content of dry fat free cancellous bone. Schroeder et al (1967) showed a similar pattern of distribution with age in the zinc content of kidney as we did in bone.

Bone strength is generally correlated with the bone-mineral content (Bartley et al 1966; Nokso-hoivisto et al 1976). In our work it was not possible to compare the zinc concentration with mineral density because they were expressed in non equivalent units of $\mu\text{g/g}$ and g/cm^3 . The zinc concentration of cancellous bone was related to bone strength. It is difficult to explain what part collagen and what part mineral play in the strength of bone.

In osteoporosis the basic abnormality is imbalance between bone resorption and apposition. Zinc is needed in bone formation especially in matrix (Bergman et al 1972). It is also evident from animal tests that extremely high dietary concentrations of zinc decrease the total ash content of bone (Huxley & Leaver 1966). Hence the relationship of zinc to bone mineral is complicated.

In conclusion we can state that the zinc content of bone is related to age and bone strength. The role of zinc in osteoporosis is obscure and requires further studies.

REFERENCES

- Aitken, J M (1976) Factors affecting the distribution of zinc in the human skeleton *Calc Tiss Res* 20 23-30
- Bartley, M H Jr, Arnold J E, Haslam R K & Jee W (1966) The relationship of bone strength and bone quantity in health, disease and aging *J Geront* 21 517-521
- Becker R O, Spadaro J A & Berg T W (1968) The trace elements of human bone *J Bone Jt Surg* 50 A 326-334
- Bergman B, Iriberg U, Lohmander S & Öberg T (1972) The importance of zinc to cell proliferation in endochondral growth sites in the white rat *Scand J Dent Res* 80 486-492
- Calhoun N R, Smith J C Jr & Becker, K L (1974) The role of zinc in bone metabolism *Clin Orthop* 103 212-234
- Frost H M (1966) Bone dynamics in metabolic bone disease *J Bone Jt Surg* 48 A 1192-1203
- Fujioka M & Lieberman I A (1964) A zinc requirement for synthesis of deoxyribonucleic acid by rat liver *J Biol Chem* 239 1164-1167
- Haumont S & McLean F C (1966) Zinc and physiology of bone. In *Zinc metabolism* Ed Prasad A S pp 169-186 Thomas Springfield Illinois
- Huxley H G & Leaver, A G (1966) The effect of different levels of dietary zinc and calcium upon the zinc concentration of the rat femur and incisor *Arch oral Biol* 11 1337-1344
- Karjalainen P (1973) A method for determination of the mineral content and mineral density of the distal radius using gamma ray attenuation *Ann clin Res* 5 231-237
- McBean I D, Dove J T, Halsted J A & Smith J C Jr (1972) Zinc concentration in human tissues *Amer J clin Nutr* 25 672-676
- Milne Devie D (1970) Methodology of zinc determinations and the role of zinc in biochemical processes *Adv clin Chem* 13 271-333
- Rokso Koivisto V M, Alhava I M & Ollonen H (1976) Measurement of cancellous bone strength *Ann clin Res* (in press)
- Nusbaum R I, Butt I M, Gilmour T C & DiDio S I (1965) Relation of air pollutant to trace metals in bone *Arch environ Health* 10 227-232
- Ollonen H, Vesilä A & Perttula T (1974) Zinc analysis of biological material by a created semiconductor detector X-ray fluorescence method (to be published)
- Patomäki I & Ollonen H (1974) Determination of mineral density and structural inhomogeneity of trabecular bone in vitro by X-ray fluorescence line scanning *Int J Appl Rad Isot* 25 401-406
- Schroeder, H A, Nason A P, Tipton I H & Balassa J J (1967) Essential trace metal: zinc. Relation to environmental cadmium *J chron Dis* 20 179-210
- Spadaro J A & Becker R O (1970) The distribution of trace metal ions in bone and tendon *Calc Tiss Res* 6 49-54
- Strehlow C D & Kneip T J (1969) The distributions of lead and zinc in the human skeleton *Amer Ind Hyg Assoc J* 30 372-378

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SERUM ELECTROPHORETIC PATTERN IN OSTEOARTICULAR TUBERCULOSIS

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Sciences Banaras Hindu University, Varanasi India

A serum electrophoretic study was carried out in 37 established osteo-
articular tuberculosis cases. The result of this study has been analysed
according to severity and chronicity and also after treatment including
certain streptomycin resistant cases. It has been observed that there
was a decrease in albumin and an increase in Alpha₂ and gamma
globulin fractions of serum protein as the disease became more ad-
vanced and chronic in nature. The administration of known antituber-
cular drugs reverses this phenomenon. The resistant cases revealed an
increase in gamma globulin fraction at almost the same level as ob-
served in the untreated cases.

Key words: tuberculosis, serum electrophoresis

Accepted 7.7.76

In spite of a good regimen of chemo-
therapy tubercular infection may persist
in some osteoarticular lesions for a
number of months (Debaumont 1966).
This raises the question that it might
be developing resistance to the standard
intitubercular therapy. However, there
are no parameters available by which
one can exclude those cases that are
acquiring resistance to streptomycin
therapy. Moreover there are very few
criteria through which the effectiveness
of any therapeutic trial can be assessed.

It is a well established phenomenon
that patients with tuberculosis invariably
become hypoproteinaemic due to
undernourishment. Under the circum-
stances variations in different fractions
of protein are known to occur both
quantitatively and qualitatively, and
these conditions are referred to as para-
proteinemia and dysproteinemia re-

spectively. This alteration of different
protein fractions has been demonstrated
in various other diseases such as Kala-
azar, nephrotic syndrome and pulmonary
tuberculosis (Narsimha & Sadasivudu
1964). However, no reports are available
where the protein fractions in skeletal
tubercular cases have been studied.

PATIENTS AND METHOD

We studied 57 cases. 20 were normal and 37
were suffering from osteoarticular tuberculosis.
Out of the 37 cases of osteoarticular tuberculosis
there were 10 cases of osteoarticular tuberculosis
(e.g. hip, knee, spine, etc.). Twenty one were male and 16 were female. All
cases were in different age groups ranging from
14 to 45 years. The diagnosis was established by

- (1) Clinical examination
- (2) Radiological examination of the local le-
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REFERENCES

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SERUM ELECTROPHORETIC PATTERN IN OSTEOARTICULAR TUBERCULOSIS

G C PRASAD K BALDEN P K SHUKLA & P J DESHPANDE

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Key words: tuberculosis, serum electrophoresis

Accepted 7.1.76

In spite of a good regimen of chemotherapy tubercular infection may persist in some osteoarticular lesions for a number of months (Debaumont 1966). This raises the question that it might be developing resistance to the standard antitubercular therapy. However, there are no parameters available by which one can exclude those cases that are requiring resistance to streptomycin therapy. Moreover there are very few criteria through which the effectiveness of any therapeutic trial can be assessed.

It is a well established phenomenon that patients with tuberculosis invariably become hypoproteinaemic due to undernourishment. Under the circumstances variations in different fractions of protein are known to occur both quantitatively and qualitatively and these conditions are referred to as proteinuria and dysproteinemia respectively.

This alteration of different protein fractions has been demonstrated in various other diseases such as kala-azar, nephrotic syndrome and pulmonary tuberculosis (Narsimha & Sadasivudu 1964). However, no reports are available where the protein fractions in skeletal tubercular cases have been studied.

PATIENTS AND METHOD

We studied 57 cases. 20 were normal and 37 were suffering from osteoarticular tuberculosis. Out of the 37 cases of osteoarticular tuberculosis there were five with neurological complications (e.g. tingling sensation in the lower limb, paraplegia, loss of urinary bladder control etc.). Twenty one were male and 16 were female. All cases were in different age groups ranging from 14 to 45 years. The diagnosis was established by

(1) Clinical examination

(2) Radiological examination of the local lesion both anteroposteriorly and laterally

SERUM β_1 IN NORMAL & β_1 & β_2 IN TYPICAL
POTT'S CASES WITH NEUROLOGICAL DEFICIT

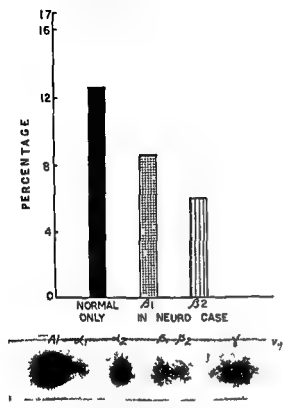


Figure 1 The extra β_2 band in serum electrophoretic strip in the cases of Pott's spine with neurological complications

(3) Mantoux test

(4) Erythrocyte sedimentation rate

Then a blood sample was taken from each patient for serum electrophoretic study. After fixation and staining of the filter paper strips, each

fraction of protein was eluted by calorimetric readings for quantitative estimation.

The levels of Albumin, α_1 , α_2 , β_1 , β_2 and Gamma fractions of serum protein were analysed according to the severity and chronicity of the disease. The electrophoretic analysis of protein was repeated after two and four months of the standard regimen of antitubercular treatment. For analysis according to chronicity the cases were divided into three main groups:

- Those having the lesion for up to six months
- Seven months to one year
- More than one year

Similarly, these cases were also divided into three grades depending on the severity of the disease i.e., Grades I, II and III.

RESULTS

Results of this study on 37 patients were analysed according to the grades and chronicity. In addition, the normal values of 20 individuals were compared with the normal values reported in the literature.

Serum electrophoretic pattern according to grades

It has been observed that there was a gradual decline in the level of serum albumin fraction as the disease advanced from Grade I to Grade III, in comparison with the normal values (Table 1). An

Table 1 Serum protein analysis according to grades

Grade	Albumin % Range Mean		Globulin							
			α_1 %		α_2 %		β %		Gamma %	
	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean
I	37.12	44.92	3.55	5.60	8.09	10.43	12.72	16.24	20.29	22.81
	49.71		7.52		11.78		19.24		26.16	
II	36.10	43.35	4.74	6.65	7.93	11.63	10.17	14.47	20.46	23.90
	51.07		9.30		15.32		17.51		26.27	
III	24.05	30.58	1.41	4.90	8.89	14.38	10.03	10.34	21.22	29.80
	46.39		7.27		22.2		20.00		48.90	
Normal		52.87		5.19		9.04		12.64		20.26

Table 2 According to chronicity

Chronicity	Albumin %		Globulin				Gamma %	
	Range	Mean	Alpha ₁ % Range Mean	Alpha ₂ % Range Mean	Beta % Range Mean		Range	Mean
Up to 6 months	20.55	34.11	3.10	5.55	7.62	13.86	8.33	13.33
	47.70		11.64		18.05		17.38	39.37
6 months to 1 year	25.35	43.25	2.72	4.93	7.31	12.70	10.40	19.31
	51.31		7.51		22.20		19.25	29.33
1 to 2 years	24.05	37.80	2.74	4.74	9.59	11.31	10.77	30.29
	47.94		7.27		15.15		20.00	48.71

estimate of the Alpha₁ fraction showed a gradual increase in Grade I and also in Grade II followed by a small decrease in Grade III whereas the other globulin fraction, i.e., Alpha₂, revealed a gradual increase in the level as the disease advanced from Grade I to III. The gamma fraction of serum globulin showed an increase in the level as the disease advanced from Grade I to Grade III (Table 1).

Serum electrophoretic pattern according to chronicity

Analysis of the albumin fraction of serum protein showed a decrease in the concentration as the disease became more and more chronic in nature. The Alpha₁ and Alpha₂ fractions of serum protein did not reveal much difference in comparison with the normal level. Similarly the Beta fraction was on a higher level throughout the period with little change according to the chronicity. The most important observation made in connection with the chronicity was in the level of the gamma fraction of serum globulin. The level of gamma globulin increased as the disease became chronic in nature (Table 2).

Pott's spine with neurological complications

In this series we have included only those three paraplegic cases who had lost

their control of the urinary bladder and anal sphincters. Significant observations made in all these cases were that there was an extra band of Beta fraction of serum globulin. This was labelled as Beta₁ fraction (Figure 1). The Beta fraction of serum protein also showed a much lower value in comparison with those cases of osteoarticular tuberculosis without neurological complications. However, the total value of Beta fraction (Beta₁ and Beta₂) in these cases was almost the same as in the uncomplicated cases. Also the values of other protein fractions were almost the same as observed in the uncomplicated cases.

Effect of operation

The electrophoretic analysis of serum proteins in these paraplegic cases was repeated two months later after operative intervention. It was observed that the extra band of the Beta fraction of globulin had disappeared without much change in the Beta₁ fraction. The albumin fraction increased to 51.61 per cent from a previous value of 47.19 per cent, whereas the gamma globulin fraction of protein decreased from 25.65 per cent to 19.48 per cent two months after operation.

Effect of antitubercular treatment

Those cases treated with standard antitubercular therapy (Streptomycin 1 g.

SERUM G₁ β 7 IN NORMAL & β 17 & β 27 IN TYPICAL
POTT'S CASES WITH NEUROLOGICAL DEFICIT

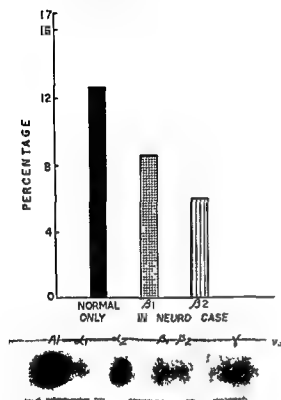


Figure 1 The extra Beta₁ and in serum electrophoretic strip in the cases of Pott's spine with neurological complications

(3) Mantoux test

(4) Erythrocyte sedimentation rate

Then a blood sample was taken from each patient for serum electrophoretic study. After fixation and staining of the filter paper strips each

fraction of protein was eluted by colorimetric readings for quantitative estimation.

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Chronicity	Albumin %		Alpha ₁ %		Globulin				Gamma %	
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6 months to 1 year	25.33	43.25	2.72	4.98	7.31	12.70	10.50	14.31	19.31	24.86
	51.31		7.51		22.20		19.25		29.33	
1 to 2 years	24.05	33.90	2.74	4.74	9.59	11.31	10.77	14.43	30.29	35.73
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Treatment	Albumin %		Globulin							
	Range	Mean	Alpha ₁ %		Alpha ₂ %		Beta %		Gamma %	
			Range	Mean	Range	Mean	Range	Mean	Range	Mean
Before	28.05	34.88	3.58	5.41	7.85	12.77	8.75	12.11	29.65	34.83
	43.02		7.93		17.68		15.68		39.37	
After 2 months	35.12	42.07	1.66	4.74	7.96	11.67	5.35	11.03	21.17	30.50
	51.27		9.92		15.28		15.93		34.32	
After	46.36	47.70	4.03	5.65	11.29	11.22	12.10	16.05	17.74	19.38
	54.84		7.27		15.15		20.00		21.21	

Isonex 300 mg, and P A S 6 g daily for two months) showed a gradual increase in the albumin fraction of serum protein at different intervals during follow-up. The Alpha₁ and Beta fractions of serum globulin did not reveal any significant change during treatment, whereas the Alpha₂ decreased in the subsequent follow-up. The gamma-globulin fraction which was higher before starting the treatment showed a rapid fall in concentration during treatment (Table 3).

Serum electrophoretic pattern in streptomycin-resistant cases

In this series we have included those cases who had full antitubercular treatment for two months or more, but had produced no beneficial effect. The electrophoretic study of serum protein in these cases revealed a decrease in the albumin fraction and a significant increase in the gamma-globulin fraction, which was almost at the same level as those who had no previous antitubercular treatment. Remaining fractions, i.e., Alpha₁, Alpha₂ and Beta did not show much difference.

DISCUSSION

Seibert et al (1947) were probably the first to report the serum electrophoretic pattern in pulmonary tuberculosis cases.

Their investigations showed an increase in Alpha₁ and gamma-globulin fractions in the early stage of tuberculosis. They have further pointed out that in chronic illness all the globulin fractions tend to be raised. Narsimha & Sadasivudu (1964) have also observed a high gamma globulin and a decrease in albumin fraction in pulmonary tuberculosis, which was confirmed by the work of Blokhin & Syromyatnikova (1964). However, none of these workers have studied the electrophoretic pattern at the various stages of skeletal tuberculosis nor have they correlated the response of antitubercular treatment.

The results of our study, when classified according to the grade and chronicity of osteoarticular tuberculosis cases, indicate that the Alpha₁ fraction of serum globulin increases gradually as the disease becomes more advanced and chronic in nature. The increase in serum gamma globulin corroborates the observation by Schaffner et al (1953) who attributed the increase in gamma globulin to immunological factors. It suggests that as this disease becomes more and more advanced, there is more demand for antibody production in the body. Since the main function of the plasma proteins, particularly of the albumin fraction, is the maintenance of plasma-osmotic pressure, the decrease in the level of this fraction

in the serum suggests that it is probably due to undernourishment of the tissue in these cases. Our study also suggests that by measuring the albumin, Alpha and gamma globulin fractions of serum protein the severity of the disease can be determined.

A similar observation was made in the cases of Pott's spine with neurological complications when an extra band of Beta₂ globulin was observed. This disappeared after compression was relieved. It is very difficult to interpret this extra Beta fraction of serum protein at this stage although it was a constant finding. However it may be possible that this extra band is due to compression over the spinal cord.

Those skeletal tuberculosis cases treated with standard antitubercular therapy showed a fall in gamma globulin fraction of serum protein after 2 to 4 months of treatment in comparison with the pre-treatment value. Whereas the albumin fraction had a decreasing tendency in the early stages it started increasing to reach a normal level after treatment. This confirms our findings that raised gamma globulin and decreased albumin occurs in tubercular cases that have responded to the antitubercular treatment. Thus these values could be taken as one of the main quantitative criteria for assessing the effectiveness or the extent of the lesion and response to any antitubercular drugs.

Some of the established osteoarticular

tuberculosis cases did not respond to the antitubercular treatment. In these cases gamma globulin fraction was found to be raised even after treatment. These studies suggest that probably by measuring the albumin and gamma globulin fraction of serum protein one may find out whether the disease is responding to antitubercular therapy, or becoming resistant to streptomycin, even in the early stages.

ACKNOWLEDGEMENT

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REFERENCES

- Blaklin V. V. & Syromyatnikova V. V. (1964) Electrophoretic studies on serum protein fraction in various stages of osteoarticular tuberculosis in rabbits. *Russian Bulletin* 10 509-513.
- Debaumont A. (1966) Bacteriologie de la tuberculose osteoarticulaire sous chimiothérapie. *Tuberc Res* 15 120.
- Narsimha Rao B. C. V. & Sadasivudu B. (1964) The electrophoretic pattern of protein in serum and ascitic fluid in tuberculosis abdomen. *J. Ass. Phys. (India)* 12 723-726.
- Schaffner F., Turner G. C., Fslough H. E., Buckingham W. D. & Popper H. (1953) *Arch intern med* 92 410.
- Seibert F. B., Atto A. S. & Campbell H. W. (1917) Variation in protein and polysaccharide content of sera in chronic disease tuberculosis sarcolosis carcinoma. *J. clin Invest* 26 90.

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REFERENCES

- Blokhin N. V. & Syromyatnikova N. V. (1974) Electrophoretic studies on serum protein fraction in various stages of osteoarticular tuberculosis in rabbits. *Russian Bulletin* 10 509-513.
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MUSCLE BLOOD FLOW AFTER AMPUTATION WITH SPECIAL REFERENCE TO THE INFLUENCE OF THE AMPUTATION LEVEL

Assessed by 133 Xenon and Histamine

An Animal Experiment

CHR HANSEN-LETH

The Department of Orthopaedic Surgery U, Rigshospitalet (Copenhagen) and
The Orthopaedic Hospital (Copenhagen)

Amputation on rabbits was found to change the muscle blood flow (MBF) in the limb subjected to surgery as well as in the contralateral extremity, depending on the technique used for amputation and the level at which it was carried out. Amputation was immediately followed by a reduction in MBF in the stump. After amputation of the crus and knee disarticulation the flow was normalized a few days later and exceeded the preoperative mean flow. After amputation of the femur such an increase in flow was not seen, but when osseous plugging of the medullary cavity was applied the MBF in the stump was intensified even after amputation of the femur.

Key words: amputation, knee disarticulation, medullary plugging, muscle blood flow, myoplasty, 133 Xenon-clearance method.

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In a previous study (Hansen-Leth 1976) it was demonstrated that assessment of the muscle blood flow (MBF) by 133 Xenon and Histamine (Lindbjerg 1965) was a valuable means of evaluating the vascular changes in rabbits undergoing amputation. After amputation of the crus, an increased MBF was found in the amputation stump. If the stump was closed by myoplasty the flow was intensified and osseous plugging of the medullary cavity resulted in a further increase in MBF.

In this study MBF was measured after amputation of the crus and femur in order to investigate the influence of the

amputation level. Furthermore, amputation with myoplasty and osseous plugging of the medullary cavity was compared with knee disarticulation in order to establish whether MBF might be influenced by surgery on muscle and bone.

MATERIAL AND METHOD

Twelve one adult rabbits were subjected to amputation of the left hind leg. In nine cases amputation was performed on the crus in six cases on a proximal site at the tibiofibular synostosis combined with myoplasty and osseous medullary plugging and in three cases at a distal level at the transition between muscle and tendon of the triceps surae using myo-

plasty knee disarticulation was carried out in four animals. In two of these, disarticulation was combined with simultaneous partial resection of the femoral condyle. In a secondary stage the condyle was removed and the medullary cavity was exposed. In eleven animals amputation of the femur was performed with myoplasty; three of these had been subjected to amputation of the crus prior to amputation of the femur. In four cases, amputation of the femur was combined with osseous plugging of the medullary cavity.

To investigate the influence of incisions into skin and muscle on the MBF, the crus and femur of five rabbits were incised and MBF subsequently measured. In a further five animals the immediate changes in MBF after fracture of the crus were investigated.

Surgery was performed in sterile conditions while the animals were under Nembutal anaesthesia. After amputation through the bone the muscles were joined over the stump. Cortex from the removed bone was used for the medullary plugging. In the cases of knee disarticulation the patellar ligament was sutured to the cruciate ligaments over the femoral condyle. In the fracture cases the intermediate part of the crus was exposed, a partial osteotomy was performed and the bone was fractured. Healing was uncomplicated in 20 cases and a defect developed on the tip of the stump in one rabbit. After amputation of the crus the animals usually put weight on the stump while after knee disarticulation of the femur the stump was immobilized with a flexion contracture in the hip.

After the operations the MBF in quadriceps and triceps surae on both sides was determined by means of ^{133}Xe and histamine thus agreeing with previous procedures (Hansen & Leth 1976). The calculated MBF was expressed in per cent of the normal blood flow in the muscles concerned previously determined in 20 rabbits prior to operation. MBF was measured postoperatively on 121 occasions within periods of time from 1 hour up to 120 days after operation, with a total of 375 single measurements.

RESULTS

In agreement with findings in a previous study (Hansen & Leth 1976), the course of the clearance curves was in general monophasic, and the fall set in immediately after the depot had been established. In about one third of all the measurements, however, an initial sta-

tionary phase was seen, and measurements of the flow in the amputation stump also revealed that the rectilinear fall after 5 to 8 minutes was followed by a terminal rise in clearance.

It seems that MBF in the amputation stump generally was decreased one hour after operation (Figure 1). After amputation of the crus, the mean flow was 76 per cent of the preoperative flow and after amputation of the femur, it was 55 per cent.

Incision into skin, whether on the crus or femur, was also found to reduce the MBF in triceps surae (mean flow 65 per cent), and after incision into muscle the mean flow was 89 per cent. Immediately after fracture of the crus the mean flow was 108 per cent of the preoperative flow.

After amputation proximally on the crus, combined with medullary plugging, the flow in the stump was increased up to 270 per cent on an average, while amputation distally on the crus, with myoplasty, was followed by an increase up to a mean flow of 170 per cent in the second week after operation. After this period the flow was normalized.

After disarticulation in the knee an increase in MBF in the left quadriceps was seen from day 3 after the operation, and the flow was increased throughout the period of investigation (Figure 1). Partial resection of the femoral condyle did not change this reaction, MBF was increased as seen after disarticulation, and from 4 to 130 days postoperatively the mean flow was 140 per cent. After total removal of the femoral condyles, including opening of the medullary cavity, the flow was immediately reduced, but from day 3 it increased to a mean flow of 140 per cent and normalized again within a couple of weeks.

Figure 1 illustrates that amputation of the femur was followed by an initial reduction and a later normalization in MBF in the stump, and in contrast to findings after amputation on a more dis-

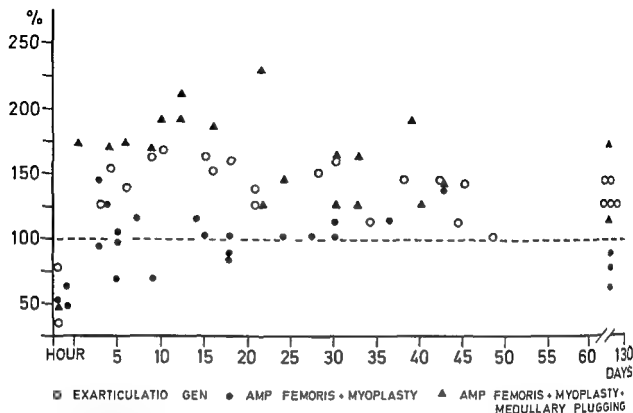


Figure 1 MBF in the amputation stump after knee disarticulation and after amputation of the femur with myoplasty and myoplasty combined with osseous medullary plugging from 1 hour to 130 days after operation

tal level, the flow in the amputation stump was not increased. Similar changes were observed if amputation of the femur was preceded by amputation of the crus. In the three rabbits in question, the mean flow in the crus stump was 290 per cent, while in the femoral stump it was 110 per cent of the pre-operative flow.

If amputation of the femur were combined with osseous medullary plugging, the initial reduction in MBF in the stump rapidly turns into an increased perfusion (mean flow 164 per cent) which remains intensified up to 10 weeks after the operation (Figure 1).

After amputation of the crus and after incision on skin and muscle, the mean flow in the contralateral quadriceps was slightly increased. After knee disarticulation, the rise in flow in the ipsilateral quadriceps was followed by a uniform increase in MBF in the contralateral

quadriceps (mean flow 131 per cent), but after amputation of the femur, the mean flow in the contralateral quadriceps was not intensified (97 per cent). When amputation of the femur was combined with osseous medullary plugging the increased MBF in the amputation stump was followed by an intensified flow in the contralateral quadriceps (mean flow 118 per cent). It appears, in general, that change in MBF in the ipsilateral quadriceps is followed by a uniform change in the flow in the contralateral quadriceps.

DISCUSSION

In agreement with a previous investigation (Hansen Leth 1976), it was demonstrated in this study that MBF in the amputation stump was reduced immediately after operation, which may be explained by an involuntarily provoked

spasm (Eriksen & Olerud 1966). The reduction in MBF in the crus stump was followed by a uniform decrease in flow in the contralateral triceps surae. A similar reaction was seen after incisions into skin and muscle while the MBF was not reduced after a fracture of the crus. It has been observed by several investigators that trauma to an extremity was followed immediately by an increased perfusion and a decreased flow in the contralateral extremity. Sandegård (1974) observed that repeated blows to the femur of dogs brought about an increase in MBF, conversely, there was no similar change in flow after a closed fracture of the femur. On the other hand, Wray (1964) observed in dogs that a closed fracture of the tibia was followed by an increased flow in the injured extremity and a reduced flow in the contralateral extremity. Periosteal stripping and drilling through bone was not found to result in a changed flow, whereas trauma on only muscle would result in an increased MBF.

Contrary to these findings, amputation brought about a decrease in MBF in the amputation stump, a reaction which must be of importance for the primary healing of the stump. The initial reduction was more marked after amputation of the femur than after amputation of the crus, and the following rise in flow, seen after amputation of the crus, was not seen after amputation of the femur. After knee disarticulation, a moderate though persistent rise in MBF occurred in the ipsilateral and the contralateral quadriceps. Resection of the femoral condyle had no influence on the flow.

It has been demonstrated in a previous study (Hansen-Leith & Reumann 1973) that the level at which amputation is performed may play a role in the vascular reaction to amputation. By arteriography, it has been demon-

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According to these findings, the level at which amputation was performed was mainly responsible for the maintenance of the MBF in the amputation stump. Another factor of importance was the closure of the medullary cavity. It was observed in a previous study (Hansen-Leith 1976) that MBF increased to a greater extent after osseous medullary plugging than after closure by myoplasty. In agreement with this observation, MBF increased when amputation of the femur was associated with plugging of the medullary cavity. It has previously been shown that plugging of the medullary cavity might stimulate growth of bone (Trueta 1933), and Kellervä et al (1970) demonstrated in a clinical trial that intensification of the vascularization of bone after fracture was followed by a rise in MBF. Hult & Olerud (1962) are of the opinion that bone healing of the amputation stump is analogous with healing of a fracture. The findings obtained in this study are in agreement with this supposition.

It has previously been observed that immobilization of an extremity without any other intervention may cause changes in the vascular conditions. Imig et al (1953) measured the flow directly

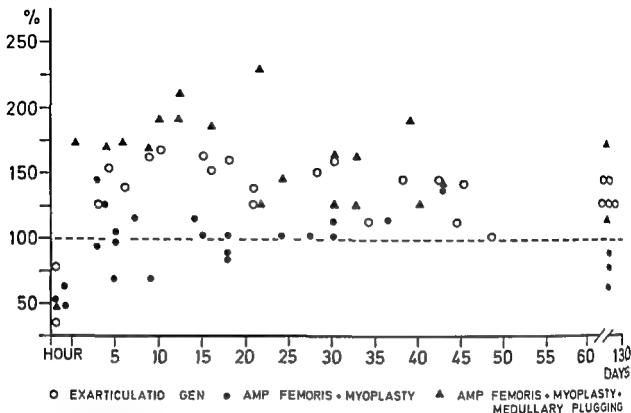


Figure 1 MBF in the amputation stump after knee disarticulation and after amputation of the femur with myoplasty and myoplasty combined with osseous medullary plugging from 1 hour to 130 days after operation

tal level, the flow in the amputation stump was not increased. Similar changes were observed if amputation of the femur was preceded by amputation of the crus. In the three rabbits in question, the mean flow in the crus stump was 290 per cent, while in the femoral stump it was 110 per cent of the pre-operative flow.

If amputation of the femur were combined with osseous medullary plugging, the initial reduction in MBF in the stump rapidly turns into an increased perfusion (mean flow 164 per cent) which remains intensified up to 10 weeks after the operation (Figure 1).

After amputation of the crus and after incision on skin and muscle, the mean flow in the contralateral quadriceps was slightly increased. After knee disarticulation, the rise in flow in the ipsilateral quadriceps was followed by a uniform increase in MBF in the contralateral

quadriceps (mean flow 131 per cent), but after amputation of the femur, the mean flow in the contralateral quadriceps was not intensified (97 per cent). When amputation of the femur was combined with osseous medullary plugging, the increased MBF in the amputation stump was followed by an intensified flow in the contralateral quadriceps (mean flow 118 per cent). It appears, in general, that change in MBF in the ipsilateral quadriceps is followed by a uniform change in the flow in the contralateral quadriceps.

DISCUSSION

In agreement with a previous investigation (Hansen Leth 1976), it was demonstrated in this study that MBF in the amputation stump was reduced immediately after operation, which may be explained by an involuntarily provoked

spasm (Eriksen & Olerud 1966). The reduction in MBF in the crus stump was followed by a uniform decrease in flow in the contralateral triceps surae. A similar reaction was seen after incisions into skin and muscle while the MBF was not reduced after a fracture of the crus. It has been observed by several investigators that trauma to an extremity was followed immediately by an increased perfusion and a decreased flow in the contralateral extremity. Sandegård (1974) observed that repeated blows to the femur of dogs brought about an increase in MBF, conversely, there was no similar change in flow after a closed fracture of the femur. On the other hand, Wray (1964) observed in dogs that a closed fracture of the tibia was followed by an increased flow in the injured extremity and a reduced flow in the contralateral extremity. Periosteal stripping and drilling through bone was not found to result in a changed flow, whereas trauma on only muscle would result in an increased MBF.

Contrary to these findings, amputation brought about a decrease in MBF in the amputation stump, a reaction which must be of importance for the primary healing of the stump. The initial reduction was more marked after amputation of the femur than after amputation of the crus and the following rise in flow seen after amputation of the crus was not seen after amputation of the femur. After knee disarticulation, a moderate though persistent rise in MBF occurred in the ipsilateral and the contralateral quadriceps. Resection of the femoral condyle had no influence on the flow.

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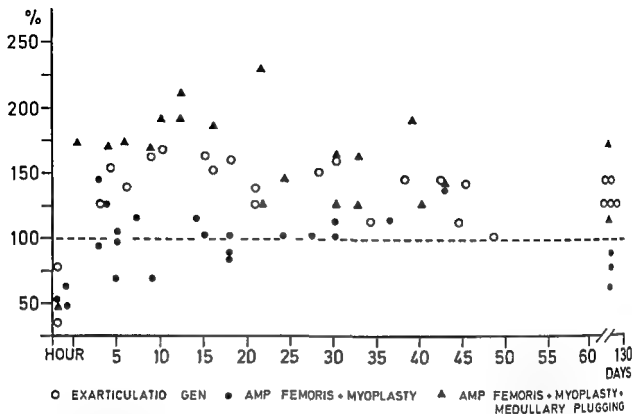


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It was observed in a previous study (Hansen-Leth 1976) that amputation of the crus intensified the MBF in the contralateral quadriceps, until it equalled the flow in the quadriceps on the side exposed to surgery. A similar increase in the flow in the contralateral quadriceps was also demonstrated after knee disarticulation, but not after amputation of the femur. An exception to this rule was that MBF in the contralateral quadriceps was also increased when amputation of the femur was combined with osseous plugging of the medullary cavity.

According to the findings in this study, the postoperative increase in MBF in the amputation stump depends on the amputation level. It is most pronounced after proximal amputation of the crus and is not seen after amputation of the femur. In agreement with a previous investigation (Hansen-Leth 1976), it has also been shown that osseous medullary plugging intensifies the flow in the amputation stump.

REFERENCES

- Ericson L (1965) Circulation in traumatic amputation stumps. *Acta radiol* (Stockh.) Suppl 239
- Ericson L & Olerud S (1966) Healing of amputation stumps, with special reference to vascularity and bone. *Acta orthop scand* 37: 20-28
- Ferguson jr A B & Akahoshi, Y (1960) Vascular patterns in immobilized, denervated or devascularized rabbit limbs. *J Bone Jt Surg* 42 A, 617-624
- Hansen Leth, C. & Reimann, I (1973) Knee disarticulation—An experimental study. *Acta orthop scand* 44, 75-86
- Hansen Leth, C. (1976) Muscle blood flow after amputation with special reference to the influence of osseous plugging of the medullary cavity—assessed by ¹³³Xenon and histamine. *Acta orthop scand* 47 613-619
- Hansen Leth, C. & Karle, A (197-) Studies on amputation in rabbits by intracardial arteriography. Submitted for publication
- Hulth, A & Olerud, S (1960) Disuse of extremities I. An arteriographic study in rabbits. *Acta chir scand* 120 220-234
- Hulth A & Olerud S (1962) Studies on amputation stumps in rabbits. *J Bone Jt Surg* 44 B, 431-435
- Imig C. J., Randall, H F & Hines, H W (1953) Effect of immobilization on muscular atrophy and blood flow. *Arch phys Med* 34, 296
- Kellerova L, Delius W, Olerud S & Strom G (1970) Changes in the muscle and skin blood flow following lower leg fracture in man. *Acta orthop scand* 41 249-260
- Lindberg I I (1965) Measurement of muscle blood flow with ¹³³Xe after histamine injection as diagnostic method in peripheral arterial disease. *Scand J clin Lab Invest* 17 371-380
- Sandegård J (1974) Vasodilation in extremity trauma. *Acta chir scand* Suppl 447
- Trueta J (1953) The influence of the blood supply in controlling bone growth. *Bull Hosp Jt Dis* 14 147-157
- Wray J H (1961) Acute changes in femoral arterial blood flow after closed tibial fracture in dogs. *J Bone Jt Surg* 43 A 1262-1268

OSTEOGENESIS AFTER BONE AND BONE-MARROW TRANSPLANTATION

I Studies with Combined Myelo-osseous Grafts in the Guinea Pig

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There has been conflicting evidence in the past regarding the contribution made to new bone formation by various components of a bone graft. This study in guinea pigs has compared cortical and cancellous bone allografts both non decalcified and hydrochloric acid decalcified inserted into a muscular site for up to thirteen days both alone and combined with autologous bone marrow. New bone formation was seen only if the implant contained fresh autologous marrow and it was not seen before the ninth day of implantation. There were no differences in the cell populations about cortical and cancellous grafts. Undecalcified bone evoked giant cell formation as well as new bone.

Key words: bone, bone transplantation, bone marrow cells, bone cells

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The stimulation of osteogenesis by combined myelo-osseous grafts has been used clinically (Boyne 1973) and experimentally (Pike & Boyne 1974) in several species.

Results from bone allografts alone have been conflicting (Nade & Burnell 1976) and the contribution of the type of bone (cortical or cancellous) or its nature (calcified or decalcified) to osteogenesis after transplantation with marrow needs further investigation.

Studies on osteogenesis in the guinea pig using bladder mucosa (Huggins 1931) and other transplants (Bang 1973) have been reported, but the combined myelo osseous graft (Burnell 1964) has not previously been used in that animal.

The morphological changes after bone and bone marrow grafting in guinea pigs are described in this paper. During the first two weeks after transplantation, new bone formation is dependent on autologous marrow. Whether the implant is calcified or decalcified does not influence osteogenesis, but giant cells are again seen around calcified implants (Nade 1970, 1973, 1976). These results are similar to earlier findings in the rabbit and rat.

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REFERENCES

- Irikson U (1965) Circulation in traumatic amputation stumps *Acta radiol (Stockh)* Suppl 238
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Table 2

Implant	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone
—	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone
Duration (days)	All allogeneic grafts alone (Not combined with marrow)			Non decalcified cortical implants combined with autologous marrow			HC decalcified cortical implants combined with autologous marrow		
1	10	10	—	3	3	—	3	3	—
3	10	10	—	3	2	—	3	3	—
5	8	8	—	3	1	—	3	1	—
7	7	7	—	3	3	—	3	2	—
9	7	7	—	3	2	2	3	3	3
11	8	8	—	3	1	1	3	3	1
13	10	10	—	3	3	3	3	2	1
Control									
Bone marrow autografts alone									
1	6	4	—	3	2	—	3	3	—
3	6	3	—	3	3	—	3	2	—
5	6	4	—	3	1	—	3	1	—
7	6	3	—	3	2	—	3	1	—
9	6	2	2	3	2	2	3	3	1
11	6	3	2	3	1	1	3	2	1
13	6	3	2	3	3	2	3	2	2

Table 1 *Types of implant used*

Source of marrow-free allogeneic bone	Treatment before freezing for storage	Whether with marrow
Iliac cancellous	Non decalcified	Alone
	Non decalcified	Combined
	HCl decalcified	Alone
	HCl decalcified	Combined
Femoral diaphyseal cortical	Non decalcified	Alone
	Non decalcified	Combined
	HCl decalcified	Alone
	HCl decalcified	Combined
Nil	Nil	Autologous marrow Alone (2 grafts)
Total		10 implants

MATERIALS AND METHODS

The experimental design was similar to that used by Salama et al (1973) and Nade & Burwell (1976), except that (i) the species studied was the guinea pig, (ii) the time period studied was up to two weeks, and (iii) autologous marrow was obtained from the femoral medullary cavity by needle aspiration through the opened knee joint.

(a) Donor bone

Cortical bone was obtained from the diaphyseal femora and cancellous bone from the ilia of killed guinea pigs. The bone for implantation was cut into pieces about 5 millimetres square. Both types of bone were decalcified in 0.6N hydrochloric acid at 2°C with continuous agitation, the cortical bone for 4 hours, and the cancellous for 15 hours.

(b) Insertion of implants

The recipients were male guinea pigs bred by the University of Sydney. Under anaesthesia the fibres of the external oblique muscle of the anterior abdominal wall were exposed, a pouch opened between these fibres and the graft inserted. The pouch was closed with a silk stitch. Ten implants were inserted into each animal—one of each of the allografts alone, and two pieces of bone-marrow autografts served as controls for the combined myelo-osseous grafts. Table 1 shows the types of implants used.

Retrieval of implants was made at 1, 3, 5, 7, 9, 11 and 13 days after insertion by killing the

animal. Three animals were used for each time period.

RESULTS

Table 2 shows the number of implants for each time period, the nature of the implants, the retrieval rate for similar implants at each time period, and new bone formation rates.

The histology is discussed in three groups.

- (a) Bone implants alone,
- (b) Bone implants combined with autologous marrow,
- (c) Marrow alone

(a) Bone alone

There was no major difference in the response seen after cancellous or cortical allogeneic bone implants.

Day 1 The osteocyte lacunae were empty. Extravasated red cells and fibrin were seen about the implants.

Day 3 Some early cellular invasion of the implant was seen, more conspicuous on the trabeculae of cancellous implants. A mild inflammatory response was noted in some sections.

Table III

Implant	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone	Number implanted	Number retrieved	Number with new bone
Duration (days)	(control)			Non decalcified cortical implants combined with autologous marrow			HCT decalcified cortical implants combined with autologous marrow		
	All iliac femoral grafts alone (Not combined with marrow)								
1	12	10	-	3	3	-	3	3	-
3	12	10	-	3	2	-	3	3	-
5	12	8	-	3	1	-	3	1	-
7	12	7	-	3	3	-	3	2	-
9	12	7	-	3	2	2	3	3	3
11	12	8	-	3	1	1	3	2	1
13	12	10	-	3	2	3	3	2	1
	(control)			Non decalcified cancellous implants combined with autologous marrow			HCT decalcified cancellous implants combined with autologous marrow		
	Bone marrow autografts alone								
1	6	4	-	3	3	-	3	3	-
3	6	3	-	3	2	-	3	2	-
5	6	4	-	3	1	-	3	1	-
7	6	3	-	3	2	-	3	1	-
9	6	2	2	3	3	2	3	2	1
11	6	3	2	3	1	1	3	2	1
13	6	3	2	3	3	2	3	2	2



Figure 1 The osteocyte lacunae of the implanted undecalcified allogeneic cancellous graft (*ob*) are empty. In the centre of the field are several multinucleated giant cells (*gc*) arranged about bone spicule. Fibrous tissue cells and stroma fill the intertrabecular interstices. (Implant duration 9 days, haematoxylin and eosin $\times 100$)

Day 5 Most implants showed evidence of connective tissue cell invasion. The degree of fibroblast infiltration appeared greater with cancellous implants.

At the periphery, the fibroblasts were arranged circumferentially. Giant cells were seen around cortical and cancellous decalcified implants. Apparent now in smaller numbers than in combined grafts were large ovoid mononuclear cells showing a round or oval, pale-staining nucleus with variable but usually faint basophilia, some had a nucleolus, a large nuclear/cytoplasmic ratio, and scanty, poorly eosinophilic cytoplasm whose boundary was often indefinable. These cells appeared more plentiful in the graft interstices, but could be seen mingled with the fibroblasts. Occasional polymorphs were noted.

Day 7 The pattern established at day 5 persisted, but showed increased fibroblast and collagen formation with encapsulation of the implant, and increased

numbers of giant cells around non decalcified implants (Figure 1).

Days 9, 11, 13 No significant change occurred. The final picture was that of a fibrous tissue encapsulated implant. The ovoid cells seen at day 5 became progressively less in number.

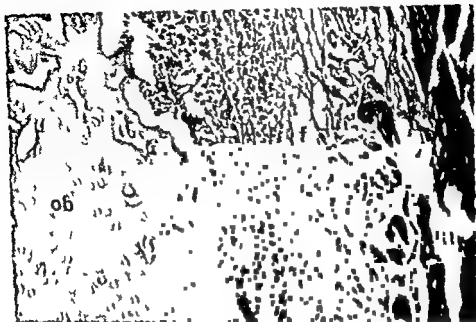
In summary, for all bone allografts implanted alone

- No new bone was seen,
- Giant cells formed only around non decalcified implants,
- No cartilage cells were seen

(b) Combined allogeneic bone and autologous marrow

There were no differences noted between cortical and cancellous bone.

Days 1 and 3 Early fibrous invasion was evident in the interstices of cancellous bone. The number of red cells was variable and probably related to the trauma of implantation. Fibrin was



usually noted. Signs of a mild inflammatory response could again be detected at the junction of implant and traumatized muscle. Marrow cells were sometimes seen but as above the presence of fat spaces was the prime guide to the transplanted marrow.

Day 7 Fibrous tissue infiltration increased, encapsulation, the transplant. Fat spaces were seen in some implants (Figure 2). Giant cells were present only in association with non decalcified grafts.

Compared with bone alone there was an abundance of the large ovoid cells described above. They were seen throughout the cancellous interstices especially but also in the fibrous capsule mingled with the fibroblasts.

Day 7 Apart from the impression of circumferential orientation of fibroblasts and collagen and the abundance of ovoid cells no difference compared with the fifth day was noted. Implanted marrow was not identifiable.

Day 9 New bone was seen in two thirds of the implants. It formed in one or two foci exhibiting a trabecular pattern in the majority. Usually one part of the new bone abutted the implant on the cancellous trabeculae with cancellous implants and on the concave surface of the cortical implant (Figure 3). In parts palisading osteoblasts were seen. The new bone was always easily identifiable when present. It was more basophilic, showed a cement line and its lacunae were small and filled by viable osteocytes.

The ovoid cells were very prominent particularly in association with the new bone. Giant cells were only seen around non decalcified implants and never related to the newly forming bone.

Days 11 and 13 Progressive fibrous and cellular infiltration of implant interstices and fibrous encapsulation was seen. The new bone was clearly recog-

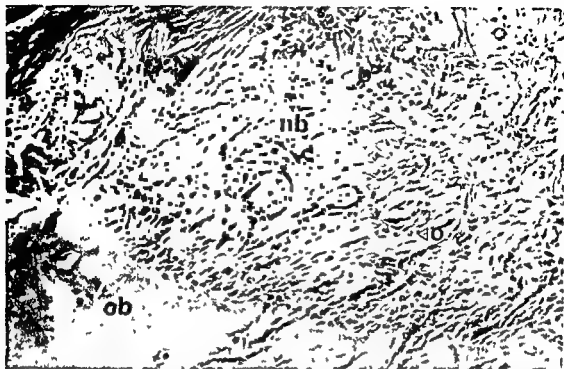


Figure 3 Newly formed bone (nb) abuts the implanted HCl decalcified allogeneic cortical graft (ob) which was combined with autologous marrow at the time of implantation. The new bone stains more deeply, contains osteocytes and is lined by osteoblasts. Ovoid cells (o) are seen amid the osteoblasts, fibroblasts and collagenous fibres. (Implant duration 9 days, haematoxylin and eosin $\times 100$)

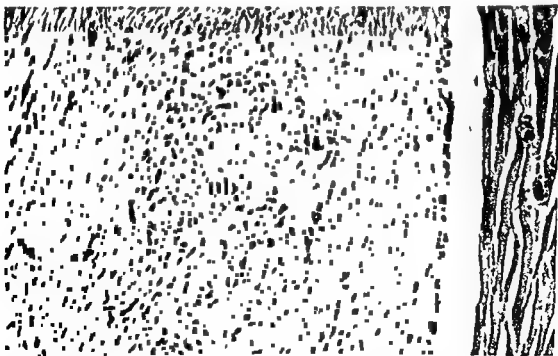


Figure 4 Newly formed bone (nb) and osteoblasts are seen at the site of an autologous bone-marrow graft 9 days after implantation. It is surrounded by fibrous connective tissue and bone-marrow cells are not identifiable. The muscle bed is adjacent. (Haematoxylin and eosin, $\times 100$)

nised near the trabeculae of new bone
oid cells were plentiful

Among the newly formed trabeculae
numerous blood vessels were seen. Giant
cells were again only seen around non
decalcified implants; they were never
associated with the new bone.

Where the new bone did not form the
appearances were the same as described
under bone implants alone.

(c) Bone marrow autografts alone

At those sites where bone formed the
sequence of cellular events followed the
same pattern as that described under
combined grafts except

- (i) No bone implant was present
- (ii) No giant cells were seen
- (iii) The number of implants forming
new bone was less than in the
combined grafts (see Table 2)
- (iv) The formation of a fibrous
capsule was less evident
(Figure 1)

In the implants not forming new bone
when the implant site was apparently
located a mixed fibrous and cellular
nodule was seen.

DISCUSSION

The history of bone graft surgery is long
and the publications on this subject are
voluminous. Although many attempts
have been made to produce a material
that would serve a useful function in a
bone bank, none has stood the test of
time. Indeed, advances in surgical and
anaesthetic techniques and modern met-
allurgy have given us the means to
provide rigidity in places where bone is
deficient and the majority of surgeons
appear to favour the use of fresh auto-
grafts of cancellous bone for osteogenic
function since their introduction by
Matth (1931), Mowlem (1941) and Ab-
bolt et al (1942).

Such grafts are in fact myelo-osseous
combinations and the current series of
investigations is an attempt to isolate the
functionally osteogenic part of the graft.
In this way further approaches to a
"bone bank" may be possible—perhaps
with the emphasis changed from the
skeletal derivation of the material which
inevitably dies to the stimuli which pro-
voke active osteogenesis by living cells.

The osteogenic potential of bone marrow

The formation of bone in sites of auto-
transplantation of bone marrow is well
established (Danis 1956, 1959, 1960, 1973;
Chalmers 1959; Burwell & Gowland 1961;
Tavassoli & Crosby 1968; Wade 1970;
Mamalis et al 1971; Patti & Maloney
1972). Although the tissue into which the
marrow is transplanted has an influence
on the formation of bone after such
transplants, Danis (1956, 1960) was able
to find newly formed bone on all sites
that he studied. The results reported in
this paper show that marrow autografts
to a muscular bed produced bone in 6
out of 42 grafts (14 per cent). If the graft
duration was greater than 7 days, bone
was found in 6 out of 18 grafts (33 per
cent). Yields of this order have also been
recorded by Burwell (1964) in rats and
Wade (1973) has shown a higher yield
in rabbits. The reasons for variability in
the yields of new bone after marrow
autografting include

- (a) difficulty in identification of the site
of marrow implantation despite se-
rial sectioning; only 8 out of 18 im-
plants were retrieved of which 6
(75 per cent) formed new bone sim-
ilar to the studies of Danis.
- (b) the possibility that cells may have
disseminated from the implant site
either by active migration or as a
result of muscle contraction. It may
be that a minimal packing density
of cells is required before bone forms
(Friedenstein et al 1966; Amsel &

Dell 1971 a) Bone implants may assist by holding sufficient marrow cells in the implanted site to allow bone formation (Burwell 1964),

- (c) There may be a phase between marrow implantation and repopulation as such during which the response to surgical trauma is no longer apparent (Maniatis et al 1971),
- (d) The possible effect of inductors or repressors of osteogenesis in the micro-environment of the transplanted marrow (Urist 1965, Nade & Burwell 1976) This study confirms that autografts of living bone marrow are osteogenic when placed into a muscular bed. Combination of autologous marrow with chemically treated, dead allografts of bone significantly increased the number of sites in which bone formed

Does the type of allogeneic bone or its treatment influence osteogenesis?

Because of their inability to reproduce the results of Urist's group, Nade & Burwell (1976) suggested that there may be differences in the influence that cortical and cancellous allogeneic bone have on bone-marrow osteogenesis. Decalcified bone as a stimulus for osteogenesis was first suggested and used by Senn (1889) and subsequent studies have shown that decalcification with hydrochloric acid may be the most effective way of producing an implant which stimulates osteogenesis (Burwell 1966, Urist et al 1968).

In this series of experiments in the guinea pig, there has been *no* (qualitative) difference shown between cortical and cancellous bone as the allogeneic component of the myelo-osseous grafts, *and also* there was no difference, in terms of new bone formation, between implants which had been decalcified with 0.6N HCl or left undecalcified.

The time of the first appearance of new bone

New bone was not seen in animals killed on the seventh day after implantation, but on the *ninth* day it had appeared. Therefore, for such an appearance of woven bone, recognisable as a tissue, the critical programming event in cell specialisation, be it differentiation of a previously uncommitted cell type, or transformation by induction, or redifferentiation, must occur in the first few days after marrow transplantation. This time sequence is not different from that found in the rabbit (Nade 1976), but contrasts with the findings of Urist et al (1972) who stated that the guinea pig was a slower bone former than other species. However, his group has experimented with bone allografts alone and claimed that an inductive process due to a component resident within decalcified bone evoked bone formation in a muscle bed 24-28 days after implantation in the rabbit. New bone formed after marrow autotransplantation forms much earlier and the cellular interactions involved may be quite different.

The cells seen about the implants

- (a) Multinucleated giant cells were seen only about non-decalcified implants—either cortical or cancellous. They were apparent as early as the fifth day and were located only about the implant and never in relation to newly formed bone. The early appearance of these cells in a *non*-sensitised animal makes a specific immune rejection mechanism unlikely. Why these cells are seen remains an enigma, but could relate to the chemical or physical composition of the allograft.
- (b) The cells described as ovoid cells appearing from the fifth day onwards may be the same as those called primitive mesenchymal cells,

reticular cells or pre osteoblasts by previous workers (see Amsel & Dell 1971 b) They appeared more plentiful in combined myelo osseous grafts and in those implants forming bone were abutting the newly formed bone Radioisotope studies or electron microscopy (Thorogood & Gray 1973) could help in their identification and warrants further study

SUMMARY

- 1 Histological study was made of the fate of bone allografts impregnated with autologous marrow and grafted to a muscular site in guinea pigs for 1 to 13 days
 - 2 Four principal types of marrow free allogeneic bone were evaluated
 - (a) Iliac cancellous bone non decalcified
 - (b) Iliac cancellous bone decalcified with HCl
 - (c) Femoral cortical bone non decalcified
 - (d) Femoral cortical bone decalcified with HCl
- Each of the four types was frozen for storage and later implanted with and without autologous marrow which was obtained from the recipient's femoral medullary cavity
- 3 New bone formation was only seen if the implant contained autologous marrow The new bone was not seen before 9 days of implantation
 - 4 Autografts of marrow alone formed bone in 6 out of 8 sites after 9 days
 - 5 There was no difference in the cell populations that formed about cortical or cancellous allografts
 - 6 Undecalcified bone cortical or cancellous evoked giant cell formation as well as new bone

ACKNOWLEDGEMENTS

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REFERENCES

- Abbott L C Saunders J B de C M & Bost F C (1912) Arthrodesis of wrist with use of grafts of cancellous bone *J Bone Jt Surg* 24 883-893
- Amsel S & Dell E (1971 a) The radiosensitivity of the bone forming process of heterotopically grafted rat bone marrow *Int J radiat Biol* 20 119-127
- Amsel S & Dell E (1971 b) Bone marrow repopulation of subcutaneously grafted mouse femurs *Proc Soc exp Biol (N Y)* 138 550-554
- Bang G (1973) Induction of heterotopic bone formation by demineralized dentin in guinea pigs: Relationship to time *Acta path microbiol scand Series A* 236 60-70
- Boyne P J (1973) Implants and transplants: Review of recent research in this area of oral surgery *J Amer dent Ass* 87 1074-1080
- Burwell R G (1964) Studies in the transplantation of bone VII The fresh composite homograft autograft of cancellous bone an analysis of factors leading to osteogenesis in marrow transplants and in marrow-containing bone grafts *J Bone Jt Surg* 46 B 110-148
- Burwell R G (1966) Studies in the transplantation of bone VIII Treated composite homograft autografts of cancellous bone Analysis I inductive mechanisms *J Bone Jt Surg* 48-B 532-586
- Burwell R C & Gowland G (1961) Studies in the transplantation of bone I Assessment of antigenicity *J Bone Jt Surg* 43 B 814-819
- Chalmers J (1959) Transplantation immunity in bone homografting *J Bone Jt Surg* 41 B 160-173
- Danis A (1956) Etude de l'ossification dans les

- greffes de moelle osseuse Monograph *Acta med belg (Brussels)*
- Danis, A (1959) In an osteogenic, skeletal tissue graft, the new formed bone develops differently according to its autologous or homologous origin *Extract du colloque international sur les problèmes biologique des greffes* 12 University of Liege
- Danis, A (1960) Après une greffe de tissu squelettique, osteogene l'est à partir des cellules transplantées que se constitue l'os de nouvelle formation *Bull Soc int Chir* 19 647-652
- Danis, A (1973) Le cal de fracture naît de la moelle osseuse directement et indirectement *Acta orthop belg* 39 696-709
- Friedenstein, A J, Piatetzky-Shapiro, I I & Petrakova K V (1966) Osteogenesis in transplants of bone marrow cells *J Embryol exp Morph* 16 381-390
- Huggins, C B (1931) The formation of bone under the influence of epithelium of the urinary tract *Arch Surg* 22 377-408
- Maniatis, A, Tavassoli, M & Croshy, W H (1971) Factors affecting the conversion of yellow to red marrow *Blood* 37, 581-586
- Mattli H (1931) Über freie transplantation von knochenspongiosa *Arch Klin Chir* 168 236-258
- Mowlem A R (1941) Bone and cartilage transplants *Brit J Surg* 29 182-193
- Nade, S M L (1970) Bone graft surgery re-appraised The contribution of the cell to ultimate success *Brit J Surg* 57, 752-756
- Nade, S M L (1973) Osteogenesis after bone transplantation—The graft, the cell and inductive phenomena *Royal Australasian College of Surgeons, 46th General Scientific Meeting Pre-printed papers* 261-262
- Nade, S M L (1976) Osteogenesis after bone and marrow transplantation II The initial cellular events following transplantation of decalcified allografts of cancellous bone (In preparation)
- Nade, S M L & Burwell, R G (1976) Decalcified bone as a substrate for osteogenesis An appraisal of the interrelation between bone and marrow in combined grafts *J Bone Jt Surg* (accepted for publication)
- Patt, H M & Maloney, M A (1972) Bone formation and resorption as a requirement for marrow development *Proc Soc exp Biol (N Y)* 140 205-207
- Pike, R L & Boyne, P J (1974) Use of surface decalcified allogeneic bone and autogenous marrow in extensive mandibular defects *Oral Surg* 32, 177-182
- Salama, R, Burwell, R G & Dickson, I (1973) Recombined grafts of bone and marrow *J Bone Jt Surg* 55 B, 402-417
- Senn N (1889) On the healing of aseptic bone cavities by implantation of antiseptic decalcified bone *Amer J med Sci* 98 219 243
- Tavassoli, M & Croshy, W H (1968) Transplantation of marrow to extramedullary sites *Science* 161, 54-56
- Thorogood, P V & Gray, J C (1975) The cellular changes during osteogenesis in bone and bone marrow composite autografts *J Anat (Lond)* 120 27-47
- Urist, M R (1965) Bone Formation by auto induction *Science* 150, 893-899
- Urist, M R, Dowell, T A, Hay, P H & Strates B S (1968) Inductive substrates for bone formation *Clin Orthop* 59 59-96
- Urist, M R, Iwata, H & Strates, B S (1972) Bone morphogenetic protein and proteinase in the guinea pig *Clin Orthop* 85 275-290

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SUPERIOR MESENTERIC ARTERY SYNDROME COMPLICATING TREATMENT WITH BALANCED TRACTION

A Case Report

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A brief review of the superior mesenteric artery syndrome is given. A case is reported which occurred after 9 weeks of treatment of a fractured femur by continuous traction with balanced suspension. The condition was successfully treated by conservative measures including a plaster hip spica allowing frequent changes of position. The importance of early diagnosis and prompt treatment is emphasized.

Key words: mesenteric artery syndrome, fracture of the femur, balanced traction, duodenal obstruction, complication to treatment.

Accepted 21 xii 76

Compression of the duodenum by the superior mesenteric artery is most often called the superior mesenteric artery syndrome. Other names, M^{I} , arterio-mesenteric ileus and Wilkie's disease, are used as well. In orthopaedic practice the syndrome is most well-known as "the cast syndrome" as it may follow body cast application for example, in the treatment of scoliosis (Dorphy 1950, Bunch & Delaney 1970, Soreff 1973, Warner et al 1974, Bisla & Louis 1975 and others).

The syndrome can also appear during prolonged bed rest in the supine position, as in the treatment of fractures by continuous traction with balanced suspension. A case of this type is reported.

CASE REPORT

An 18 year old man of asthenic habitus with no earlier gastro-intestinal symptoms sustained a fracture of the shaft of the left femur and a

fracture of the right radius but no abdominal lesions. The fracture of the femur was treated by continuous traction with balanced suspension (Figure 1). After 9 weeks of immobilization in the supine position the patient developed symptoms and signs of a high ileus. Radiographic examination (Figure 2) revealed a compression occlusion of the distal part of the duodenum. The condition was recognized as the superior mesenteric artery syndrome and it was decided to treat the patient conservatively with gastric suction and parenteral nutrition. The dehydration, alkalosis and hypokalaemia were corrected. The balanced suspension was removed, and a plaster hip spica was applied to permit frequent changes of the position of the patient. This treatment was successful and the symptoms and signs of ileus disappeared in a couple of days. The symptoms returned to a lesser degree 4 weeks later when the patient still had not been mobilized with his plaster hip spica and the changing of position was not so frequent. After 2 weeks of applying before

his plaster hip spica with a pair of crutches and treatment was continued on an outpatient basis. Since that time there have not been any gastro-

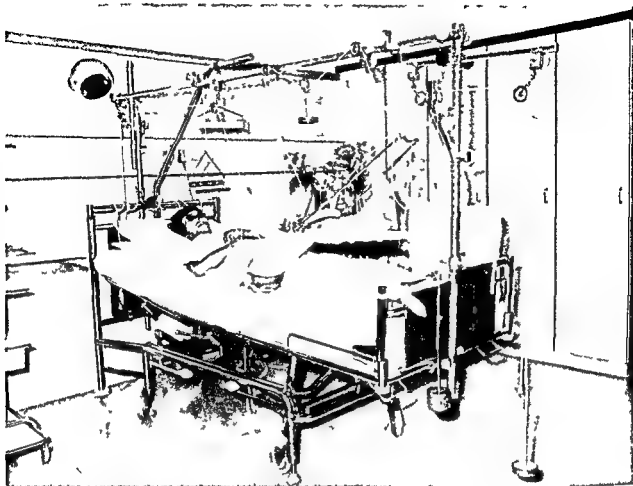


Figure 1 Sustained traction with balanced suspension as used in the case described. The patient shown is not the one reported

intestinal problems. The exact change of his weight from before the accident until the beginning of his ileus is not known, but there was a considerable weight loss.

DISCUSSION

The superior mesenteric artery syndrome is a vascular compression obstruction of the duodenum, the transverse portion of which is the most fixed part of the alimentary tract, placed retroperitoneally between the aorta and the vertebrae posteriorly and the root of the mesentery of the small bowel anteriorly. Here it is placed like a nut between the jaws of a nutcracker, with a movable anterior and an immobile posterior jaw. When the distance between the 'jaws' becomes too narrow duodenal compression occurs.

The anatomic basis of this vascular compression of the duodenum is further described by Akin et al (1974).

Several causes have been given, and some of these are

- 1 Marked rapid loss of weight including loss of the retroperitoneal fat, so that the superior mesenteric artery impinges more directly on the duodenum
- 2 Prolonged bed rest in the supine position
- 3 Asthenic habitus
- 4 Increased lumbar lordosis and decrease in the scoliosis angle
- 5 Weak abdominal musculature
- 6 Prolonged abdominal compression, e.g., by plaster body cast

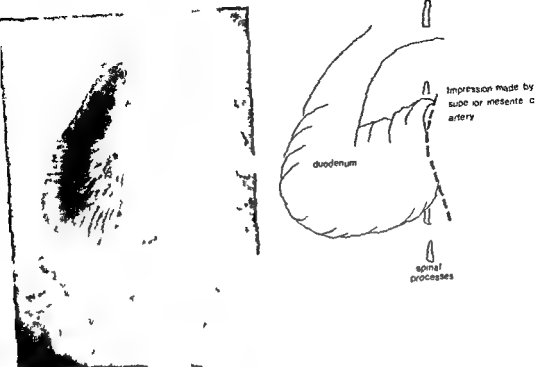


Figure 2 The radiograph findings leading to the diagnosis. A c impression at the distal part of the duodenum (AP projection the patient in the supine position)

Several of the factors are often involved in the development of the syndrome.

Three categories of the superior mesenteric artery syndrome can be distinguished. Firstly there is a group of patients who after for example a scoliosis operation and immobilization in a body cast or plaster hip spica rapidly (in a few days) develop the type of the superior mesenteric artery syndrome described as the cast syndrome. The second group includes patients with severe war injuries (Wayne et al 1971) and patients with severe burn injuries (Rechler et al 1972). Characteristic for the patients described by Wayne and Rechler is prolonged bed rest in the supine position with loss of weight followed by the superior mesenteric artery syndrome after 10 to 37 days. Patients with a more chronic and intermittent version of the syndrome constitute the third group (Jones et al 1960).

The clinical picture of the acute syndrome is that of high intestinal obstruction with gastric dilatation and vomiting of bile stained material. In the less acute form there is postprandial epigastric fullness with epigastric pain or vague and ill defined epigastric discomfort after eating. This may be associated with anorexia, malaise, nervousness, easy fatigability, marked mental depression and emotional instability. If not treated the pernicious vomiting may lead to hypovolaemia, alkalosis, hypokalaemia and to shock and death.

The diagnosis should be confirmed by radiologic examination. Under fluoroscopy with the patient in different positions the occlusion can be seen to diminish to a greater or lesser extent in some positions, a fact which can be used therapeutically. These observations under fluoroscopy also prove that the superior mesenteric artery syndrome is a reality.

This has been questioned by Cimmino (1961) and others

As soon as the diagnosis is established, prompt treatment including gastric suction, parenteral nutrition and correction of hypovolaemia and hypokalaemia should be started. If possible the position of the patient should be changed frequently. If the symptoms persist for more than 24 hours, casts and plasters should be removed. If this treatment is impossible or unsuccessful, surgical intervention is indicated.

REFERENCES

- Akin, J. T., Skandalakis, J. G. & Gray, S. W. (1974) The anatomic basis of vascular compression of the duodenum. *Surg Clin N Amer* **54**, 1361-1370.
- Bisla, R. S. & Louis, H. J. (1975) Acute vascular compression of the duodenum following cast application. *Surg Gynec Obstet* **140**, 563-566.
- Bunch, W. & Delaney, J. (1970) Scoliosis and acute vascular compression of the duodenum. *Surgery* **67**, 901-906.
- Cimmino, C. V. (1961) Arteriomeseenteric occlusion of the duodenum. An entity? *Radiology* **76**, 828-829.
- Dorph, M. H. (1950) The cast syndrome. Review of the literature and report of a case. *New Engl J Med* **243**, 440-442.
- Jones, A. S., Carter, R., Smith, I. L. & Joergensen, F. J. (1960) Arteriomeseenteric duodenal compression. *Amer J Surg* **100**, 262-277.
- Rechler, J. M., Bruck, H. M., Munster, A. M., Currere, P. W. & Pruitt, B. A. (1972) Superior mesenteric artery syndrome as a consequence of burn injury. *J Trauma* **12**, 979-985.
- Soreff, J. (1973) Duodenal obstruction i den ortopediske praktiken. *Opusc Med* **18**, 68-72.
- Warner, T. G., Shorter, R. G., McIlrath, D. C. & Dupree, F. L. (1974) The cast syndrome. An unusually severe case. *J Bone Jt Surg* **56A**, 1263-1266.
- Wayne, F., Miller, R. F. & Fiseman, B. (1971) Duodenal obstruction by the superior mesenteric artery in bedridden combat casualties. *Ann Surg* **174**, 339-345.

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EPIDERMAL BONE CYST OF THE FINGER

A Case Report

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An epidermal cyst of the terminal phalanges of the fingers is a rare finding. The present work deals with some of the clinical and pathological aspects of such a case seen by the authors.

Key words: bone neoplasms, epidermal bone cyst

Accepted 2 xii 76

Epidermal cysts of bone are quite rare. Most of them occur in the skull, but they may occasionally be observed in the distal phalanges (Bissel & Brunschwig 1937, Kleinsasser & Albrecht 1957, Roth 1964, Dahlin 1967, Lichtenstein 1970).

Because of the rarity of phalangeal epidermal cysts, the presentation of such a case may be of interest.

CASE REPORT

A 33-year-old man had for many years noticed a thickening of the distal phalanx of his left little finger but it had not caused any discomfort.

He visited his doctor because of acute pain in the finger following a slight trauma. The primary treatment was for a fracture without dislocation.

A couple of weeks later he was admitted to hospital. X-ray of the finger showed a well demarcated tumour.

A fracture line was seen crossing the cyst (Figure 1). Clinically the diagnosis was that of an enchondroma. Primary amputation of the terminal phalanx was performed because of the extension and localisation of the lesion.

Pathological examination

The specimen consisted of the distal phalanx of the left little finger. It was cut longitudinally at the midline. Most of the bony phalanx was occupied by a cystic tumour with grey, greyish coloured masses in the lumen (Figure 2).

Histological sections through the entire phalanx were prepared and stained with haematoxylin-eosin, Azan-Heidenhain and Weigert's Eosin van Gieson.

Apart from a small area, the cyst wall was seen microscopically to be lined by a regular stratified squamous epithelium. The epithelium varied in thickness, in many places with multiple layered stratum spinosum and granulosum. The cyst lumen was filled with stratified horny masses and fatty material (Figure 3). Where the covering epithelium was missing a mainly histiocytic reaction with several giant cells of the foreign type was seen. In this area the cortices seemed to be destroyed too, but the soft tissue outside the bone was only minimally affected.

DISCUSSION

According to the literature most of the patients with epidermal cysts of the phalanges are young male adults, as in the present case. A traumatic origin of the cysts following a mild to severe

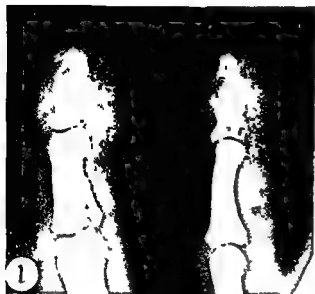


Figure 1 Roentgenograms (anteroposterior and oblique views) showing a lytic defect with a thin sclerotic border. A fracture line is seen traversing the cyst

Figure 2 Longitudinal section through the terminal phalanx of the little finger. The border of the cyst is marked

crushing type of injury is suggested by most authors. Injuries to the nailbed seem in this connection to be of importance (Behrens 1931, Fisher et al 1958, Roth 1964)

As in the present lesion, epidermal cysts may easily be confused clinically

with enchondroma, more rarely with osteomyelitis. The clinical symptoms which in our case seemed classic are not different from those of enchondroma. Radiographically epidermal cysts appear as rounded lytic areas with clearly defined borders without the mottled appearance often seen in enchondroma. The distinction may however be difficult to make (Bissel & Brunshwig 1937, Fisher et al 1958, Lichtenstein 1972)

A definitive diagnosis is established by histological examination and is dependent upon the demonstration of a squamous epithelial lining in at least some portion of the cyst wall. In cases with curetted material and prominent granulomatous reaction the impression of a benign giant cell tumour may be obtained, especially if the material is sparse (Fisher et al 1958)

The treatment of choice is curettage



Figure 3 Histological specimen showing the epidermal cyst within the bone. Horny stratified material is seen in the lumen (H.E. $\times 175$)

possibly with filling of the bony defect. Recurrence seems to be rare. Because of a marked bony defect an amputation may have to be performed as in the present case (Roth 1964).

REFERENCES

Behrens A (1931) Über traumatische Epithelcysten. *Virchows Arch path Anat* 280 145-151.
 Bessel A D & Brunschwag M S (1937) Squamous epithelial bone cysts of the terminal phalanx. *J Amer med Ass* 108 1769-1774.

Dahlin D C (1967) *Bone tumors* 2nd ed. p 259. Charles C. Thomas Springfield, Illinois.
 Fisher F R, Cruhn J & Skerret P (1958) Terminal cyst in bone. *Cancer (Phila)* 11 643-648.
 Lichtenstein L (1970) *Diseases of the hand and joints* 1st ed. p 180. C. V. Mosby Company, Saint Louis.
 Lichtenstein L (1972) *Bone tumors* 4th ed., p 29. C. V. Mosby Company, Saint Louis.
 Kleinsasser O & Albrecht H (1957) Die Epithelcyste der Schädelknochen. *J Langenbecks Arch Klin Chir* 285 498-515.
 Roth S I (1964) Squamous cysts involving the skull and distal phalanges. *J Bone Jt Surg* 46-A 1449-1450.

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ULTRASTRUCTURE OF PROLAPSED DISC

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Prolapsed tissue and removed interspace contents were obtained during hemilaminectomy for disc prolapse. The ultrastructure of the tissue was studied. Division of the material into *annulus fibrosus* and *nucleus pulposus* proved to be inaccurate. Chondrocytes were always the predominant cell type and could be classified into normal cloning and necrotized types. Matrix vesicles were found in relation to the haloes of chondrocytes and seemed to be products of disintegrated chondrocytes. Findings of crystals in the vesicles were rare. The intercellular substance showed degraded collagen fibrils, which could be seen in spindle shaped cells as well. A dense amorphous material interspersed with collagen fibrils seemed to be a glycoprotein. A few elastic fibres were found, but without any evidence of severe degeneration. These findings represent changes occurring in cells and in the intercellular substance.

Key words: intervertebral disc displacement, ultrastructure, chondrocytes, matrix vesicles, collagen, proteoglycan, glycoprotein, elastic fibres.

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Knowledge of the ultrastructure of undisplaced human discs is based on examinations of necropsies from normal spines (Sylvén et al 1951, Watanabe 1960, Dahmen 1963, Gombuchi 1964, Render 1971, Inoue 1973, Takeda 1975, Inoue & Takeda 1975) and biopsy material from scoliotic spines obtained during surgical operation for wedge resection (Cornah et al 1970, Meachum & Cornah 1970, Meachum 1972).

Hence, the interpretation of the ultrastructural findings on a prolapsed disc is hampered by incomplete knowledge of the structure of the fresh normal disc, and, furthermore, by specific difficulties

due to the mixed nature of prolapsed specimens (Brown 1971).

These may be the reasons why no comprehensive study on the ultrastructure of the displaced intervertebral disc has been carried out since 1963-64 when Dahmen, Happey et al and Gombuchi reported their findings. Because of the less developed preparation technique they used, a more detailed ultrastructural picture of prolapsed discs is still unavailable.

MATERIAL AND METHODS

Specimens were obtained during hemilaminectomy for disc prolapse from six patients (three males and three females) ranging from 31 to 70 years of age. The patients had had significant clinical symptoms for 2 to 9 months. The level

¹ Supported by a fellowship from the Danish Rheumatism Association.

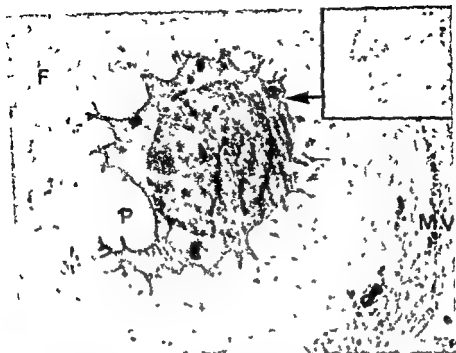


Figure 1 A chondrocyte surrounded by a halo consisting of a pericellular lacuna (P) and fine collagen fibrils (F). Outside the halo a collection of matrix vesicles (MV). $\times 6000$
Inset: Proteoglycan granules are seen in the pericellular lacuna. Ruthenium red stain $\times 60000$

herniation was L_4 or L_5 . According to surgical findings five patients had a protruded disc. One disc was found to be ruptured.

According to their anatomical position the tissue specimens were classified into a herniated part and an intervertebral part.

The tissue specimens were fixed in a 6 per cent glutaraldehyde solution in 0.1 M cacodylate buffer at pH 7.4 with 7.5 sucrose at 4°C and permeated with 1 per cent osmic acid. After dehydration of the specimens in graded alcohols they were embedded in Epon 812 and ultrathin sections were stained with uranyl acetate and lead citrate. Some sections were also stained with ruthenium red (Hobayass & Ashoe Hansen 1971) and periodic acid silver proteinate (Thiery 1967).

A Siemens electron microscope was operated at 80 kV with double condensers.

OBSERVATIONS

The chondrocytes were surrounded by a halo consisting of a pericellular lacuna and an outer fibrillar ring. Three different types of arrangements could be

identified. In one type, a single oval cell was found to be surrounded by a thick fibrillar ring made up of collagen fibrils with a diameter of 100–200 Å (Figure 1). Inside this the pericellular lacuna contained numerous granules with delicate branches. The granules stained with ruthenium red representing high contents of proteoglycans (Figure 1 inset). The chondrocyte showed a large nucleus with one nucleolus. The cytoplasm contained Golgi cisternae, distinct granular endoplasmic reticulum, a few mitochondria, lysosomes and fat droplets.

A second type of arrangement consisted of one or several cells encircled by one common halo (Figure 2). The halo was formed of an outer narrow fibrillar part and an inner broad proteoglycan part. The cells had short cytoplasmic processes which did not reach the fibrillar ring. The cells contained a well developed granular endoplasmic re-

ULTRASTRUCTURE OF PROLAPSED DISC

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Prolapsed tissue and removed interspace contents were obtained during hemilaminectomy for disc prolapse. The ultrastructure of the tissue was studied. Division of the material into *annulus fibrosus* and *nucleus pulposus* proved to be inaccurate. Chondrocytes were always the predominant cell type and could be classified into normal cloning and necrotized types. Matrix vesicles were found in relation to the haloes of chondrocytes and seemed to be products of disintegrated chondrocytes. Findings of crystals in the vesicles were rare. The intercellular substance showed degraded collagen fibrils which could be seen in spindle shaped cells as well. A dense amorphous material interpered with collagen fibrils seemed to be a glycoprotein. A few elastic fibres were found but without any evidence of severe degeneration. These findings represent changes occurring in cells and in the intercellular substance.

Key words: intervertebral disc displacement, ultrastructure, chondrocytes, matrix vesicles, collagen, proteoglycan, glycoprotein, elastic fibres.

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Knowledge of the ultrastructure of undisplaced human discs is based on examinations of necropsies from normal spines (Sylvén et al 1951, Watanabe 1960, Dahmen 1963, Gombuchi 1964, Render 1971, Inoue 1973, Takeda 1975, Inoue & Takeda 1975) and biopsy material from scoliotic spines obtained during surgical operation for wedge resection (Cornah et al 1970, Meachum & Cornah 1970, Meachum 1972).

Hence, the interpretation of the ultrastructural findings on a prolapsed disc is hampered by incomplete knowledge of the structure of the fresh normal disc and, furthermore, by specific difficulties

due to the mixed nature of prolapsed specimens (Brown 1971).

These may be the reasons why no comprehensive study on the ultrastructure of the displaced intervertebral disc has been carried out since 1963-64 when Dahmen, Happey et al and Gombuchi reported their findings. Because of the less developed preparation technique they used, a more detailed ultrastructural picture of prolapsed discs is still unavailable.

MATERIAL AND METHODS

Specimens were obtained during hemilaminectomy for disc prolapse from six patients (three males and three females) ranging from 31 to 70 years of age. The patients had had significant clinical symptoms for 2 to 9 months. The level

¹ Supported by a fellowship from the Danish Rheumatism Association

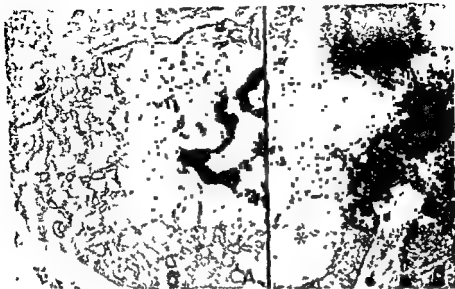


Figure 4A A spindle shaped cell containing collagen fibrils $\times 15,000$

Figure 4B Detail of engulfed collagen fibrils (asterisks) $\times 60,000$

ticulum, mitochondria, lysosomes, and dilated vesicles. The Golgi apparatus was dilated with proteoglycan figures in the cisternae (Figure 2 inset a). Fat droplets and numerous PAS positive glycogen particles were deposited in the cytoplasm of some of the cells (Figure 2 inset b).

The third type of arrangement consisted of one or occasionally two cells surrounded by an often poorly defined fibrillar ring. The cells were necrotic and had a dark cytoplasm with lucent spaces containing proteoglycan figures (Figure 3). The cytoplasmic details could not be identified except for the large fat droplets. In the immediate vicinity of the cell surface large numbers of membrane invested vesicles were found (Figure 3 inset b).

A common finding in all the observed haloes was the presence of membrane-bounded vesicles located immediately outside the fibrillar ring. They often appeared at one side of the periphery, lending the group a semilunar shape in section. In the first two of the above-described chondrocyte arrangements, the

vesicles were never found inside the halo. The individual vesicle was round, oval or kidney shaped (Figure 3 inset a). The size varied from 500 to 3,000 Å with a modal value of approximately 1,000 Å. It was bounded by a double membrane and contained a material of varying density. However, empty vesicles were also found. Sometimes the limiting membrane was disrupted, and extrusion of vesicle contents could be seen. Rarely, fine crystalline formations could be identified inside the vesicles, but only provided no counterstaining had been used.

A minority of cells had no chondrocytic appearance. These cells were spindle shaped without a halo and were always found in the dense fibrillar tissues (Figure 4). They held a distinct granular endoplasmic reticulum, lysosomes and often phagocytized collagen fibrils.

The intercellular substance consisted of collagen fibrils, proteoglycans, dense amorphous material, filament bundles with cross bonds and occasionally, elastic fibres.

In the prolapsed part of the discs, the



Figure 2. Chondrocytes surrounded by one common halo broad pericellular lacuna (P). Thin fibrous ring (F). Matrix vesicles (MV). $\times 6,000$.

Inset a. Detail of dilated Golgi cisternae containing proteoglycan figures $\times 60,000$

Inset b. Glycogen particles (GP) in the cytoplasm of a chondrocyte. Periodic acid silver proteinate $\times 30,000$.

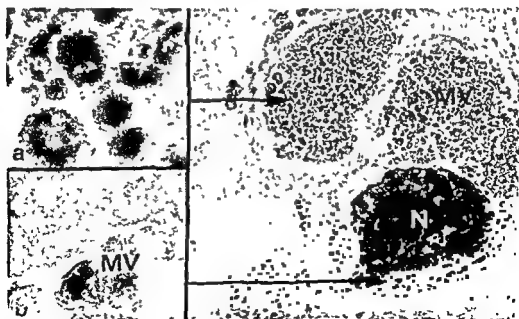


Figure 3. Necrotic chondrocyte (N). Lots of matrix vesicles (MV) are seen in the pericellular lacuna $\times 6,000$

Inset a. Pleomorphic matrix vesicles lying in cluster formation $\times 60,000$

Inset b. Matrix vesicles at the surface of necrotic chondrocyte. The plasma membrane is disrupted $\times 60,000$



Figure 3A A spindle shaped cell containing collagen fibrils $\times 15,000$

Figure 3B Detail of engulfed collagen fibrils (asterisks) $\times 60,000$

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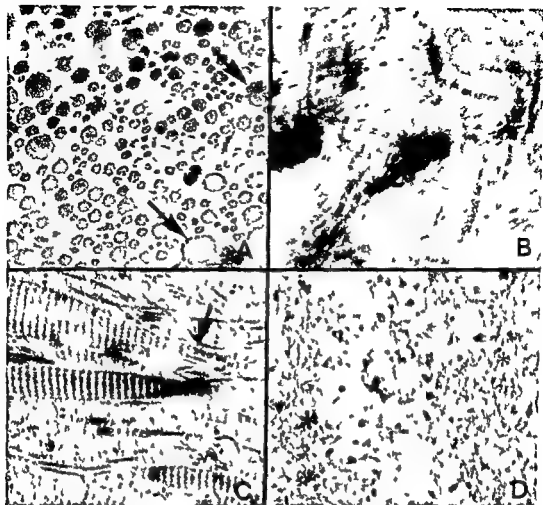


Figure 5 A Abnormal collagen fibrils showing varying diameters and irregular margins (arrows) $\times 30\,000$

Figure 5 B Disarranged collagen fibrils showing curled and lent shapes $\times 60\,000$

Figure 5 C Thick collagen fibrils showing tapered ends (arrow) $\times 30\,000$

Figure 5 D Cross banded filamentous bundles (asterisks) $\times 60\,000$

most densely packed collagen was noted while in the intervertebral part more proteoglycan figures and less collagen fibrils were present. An absolute correlation between fibrillar density and the presumed contribution of annulus fibrosus to the tissue is estimated by the *in situ* location of the specimen was however not found.

The collagen fibrils when tightly packed were running parallel to each other in firm bundles. In the case of looser arrangement no predominant direction of the fibrils was found. The axial periodicity was always normal. The range of

the diameters was 100–4 000 Å. However most fibrils had diameters within the range of 300–2 500 Å but they varied considerably between the fibrils even within small areas (Figure 5 A). Pathological phenomena such as irregular cut surfaces, curling, bending and tapered ends were common (Figure 5 A, B, C).

The dense amorphous material was seen in large compact masses or spread out interspersed between the collagen fibrils or bundles (Figure 6 A). Numerous proteoglycan figures were seen in this material. The material was periodic acid silver proteinate positive (Figure

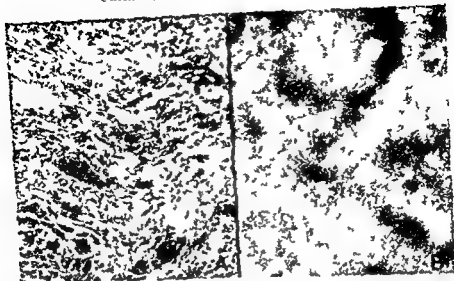


Figure 6A Dense amorphous material interspersed with collagen fibrils $\times 6000$

Figure 6B The dense amorphous material surrounding collagen fibrils shows staining with periodic acid-Schiff reaction $\times 6000$



Figure 7A Tightly packed collagen fibrils on the right hand side of the micrograph while the left the micrograph shows a loose arrangement of the collagen fibrils with proteoglycan aggregates and elastic fibers (arrows) $\times 6000$

Figure 7B The arrow pointed elastic fibre in Figure 7A. A microvesicle is seen $\times 6000$

6B while the ruthenium red staining turned out to be more faint.

Filamentous bundles with cross bands with a periodicity of 800-900 Å (Figure 6B) were usually located at the haloes of the chondrocytes. However they were never found in the first described chondrocyte type.

Elastic fibres were identified especially at the borderline between the annulus fibrosus and the nucleus pulposus (Figure 7). They appeared without fibrils but were coated with a PAS-positive material.

DISCUSSION

In the present study, the prolapsed tissue and removed contents of the disc interspace have been described.

The first chondrocyte arrangement described represents the healthy cells found in discs of scoliotic spines (Meachim & Cornah 1970, Meachim 1972) and the chondrocytes in the middle layer of normal articular cartilage (Weiss 1973, Lane & Weiss 1975). The cells are believed to take part in the normal turnover of the matrix.

The second type of chondrocyte arrangement shows cloning cells and evidence of increased secretion. It is found in degenerating cartilage (Weiss 1973) and is interpreted as an attempt at repair, compensating for loss of intercellular substance.

The third chondrocyte type characterizes a stage of cell death. Necrotic chondrocytes are a frequent observation in discs of scoliotic spines and are found in osteoarthritic cartilage as well (Weiss 1973). Surrounding the necrotic cell remnant, we found numerous membrane-bounded bodies which seem to be identical to the matrix vesicles first described by Anderson (1967) and Bonucci (1967). They are believed to play a major role in calcification of the tissue in which they are found. Their origin is still a matter of debate (Rabinovitch & Anderson 1976).

As necrotic cells in our material were the only cells having matrix vesicles in their pericellular lacuna, it seems likely that they are produced only by these cells.

The rare occurrence of crystals inside or in the vicinity of matrix vesicles disagrees with the finding that the major function of matrix vesicles should include calcification of the prolapsed disc. Whether the matrix vesicles in the prolapsed disc play a role in the degeneration of the matrix or merely reflect

necrosis of chondrocytes seems unclear.

Our finding of varying diameters of collagen fibrils has formerly been described in prolapsed tissue, but in undisplaced necropsy tissue as well (Sylvén et al 1951, Dahmen 1963, Render 1971) and, therefore, it can hardly be recognized as a pathological phenomenon. However, a greater range of diameters was found in our material. The cross sections of fibres most frequently showed irregular margins. This has been described in collagen after exposure to collagenases (Keech 1954, Kobayasi et al 1977) and is supposed to represent an effect of a collagenolytic agent.

The tapered ends of fibrils are believed to represent the same phenomenon. This type of collagen change has been described in the prolapsed disc by Dahmen (1963).

The pathological curling of fibrils has also been observed in skin disease, such as necrobiosis lipoidica (Kobayasi et al 1974) and shagreen patch (Kobayasi et al 1973). No causative mechanism of the change is known.

Cross-banded filamentous bundles appear in the intervertebral disc of humans (Cornah et al 1970) and in rabbits (Smith & Serafini-Fracassini 1968). They are described most frequently to be located in the pericellular matrix, and we believe they are a type of collagen. They have been found in other connective tissues as well, and in organ cultured skin, they have turned out to be degradative products of collagen due to collagenolytic activity (Hentzer & Kobayasi 1975). The same mechanism may be responsible for their formation in the disc.

The dense amorphous material is supposed to be a glycoprotein, as it stains heavily with periodic acid silver proteinate. Hence, the substance might be identical to a glycoprotein identified in increased concentrations in older discs (Pearson et al 1972). In our observa-

lions the affinity of the collagen for this material agrees with its preferred location between collagen fibrils

Elastic fibrils in discs have been described recently by Buckwalter et al (1976). In our specimens elastic fibres were primarily located at what we believe to be the borderline between the annulus and the nucleus. A concentration at this location is reasonable and fits with the theory that a necessary condition for their formation is a tensile force combined with a cross force (Little 1973).

ACKNOWLEDGEMENT

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REFERENCES

- Anderson H C (1967) Fle-tion in microscope studies of induced cartilage development and calcification *J Cell Biol* 33 31-101
- Bouucci E (1967) Fine structure of early cartilage calcification *J Ultrastruct Res* 20 33-50
- Brown M D (1971) The pathophysiology of disc disease *Orthop Clin N Amer* 2 309-370
- Buckwalter J A, Cooper R R & Maynard J A (1976) Elastic fibres in human intervertebral discs *J Bone Jt Surg* 58 A 77-86
- Cornah M E, Meacham G & Parry F W (1970) Banded structures in the matrix of human and rabbit nucleus pulposus *J Anat (Lond)* 107 351-362
- Dahmen G (1973) Submikroskopische Untersuchungen an Wirbelbandscheiben *Z Rheumaforsch* 27 197-213
- Combs R (1964) Electron microscope studies on the fine structure of the intervertebral disc with special reference to intervertebral disc herniation *J Jap orthop Soc* 37 1927-1931
- Happel F, Johnson A C, Taylor A & Turner R L (1961) Preliminary observations concerning the fine structure of the intervertebral disc *J Bone Jt Surg* 43 B 563-567
- Hentzer B & Kobayashi T (1975) Ultrastructural changes of human skin in organ culture *IRCS Med Sci* 3 211
- Inoue H (1973) Three-dimensional observation of collagen framework of intervertebral discs in rats dogs and humans *Arch histol Jap* 38 39-56
- Inoue H & Takeda T (1975) Three dimensional observation of collagen framework of lumbar intervertebral discs *Acta orthop scand* 46 919-936
- Kerck M H (1954) The effect of collagenase and trypsin on collagen *Anat Rec* 119 139-154
- Kobayashi T & Ashoe Hansen G (1971) Ruthenium red staining of ultrathin sections of human mast-cell granules *J Microsc* 105 55-60
- Kobayashi T, Wolf-Jurgensen P & Danielsen L (1973) Ultrastructure of shagreen patch, *Acta dermatovenereol* 53 273-278
- Kobayashi T, Danielsen L & Ashoe Hansen G (1974) Ultrastructure of necrobiosis lipoidica diabetorum *Acta dermatovenereol* 54 427-431
- Kobayashi T, Hentzer B & Ashoe Hansen G (1975) *in press*
- Lane J M & Weiss C (1972) Review of articular cartilage collagen research *Artif and Rheum* 18 553-567
- Little H (1973) Observations on the nature and production of proteins in the intercellular matrices of connective tissues *J Path* 110 1-12
- Meacham G (1972) Meshwork patterns in the ground substance of articular cartilage and nucleus pulposus *J Anat (Lond)* 111 219-227
- Meacham G & Cornah M S (1970) Fine structure of juvenile human nucleus pulposus *J Anat (Lond)* 107 337-350
- Pearson C H, Happey F, Naylor A, Turner R L, Palframan J & Shephall B (1972) Collagens and associated glycoproteins in the human intervertebral disc *Ann Rheum Dis* 31 45-50
- Rabinovitch A L & Anderson H C (1968) Biogenesis of matrix vesicles in cartilage growth plates *Fed Proc* 33 112-116
- Rander R W (1971) An investigation on using the electron microscope into the structure of the human intervertebral disc M Sc Thesis University of Bradford
- Smith J W (1975) *in press*
- Smith W, Paulson S, Hirsch C & Snellman O (1951) The ultrastructure of bovine and human nucleus pulposi *J Bone Jt Surg* 33 A 333-340

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UNILATERAL AND BILATERAL PARTIAL LAMINECTOMY IN LUMBAR DISC PROLAPSE

A Follow up Study of 156 Patients

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Martina Hapstens Hospital Sandvika Norway

The results of two comparable groups of in all 156 operated patients with lumbar disc prolapse were evaluated 4-9 years postoperatively. Sixty seven patients had received bilateral and 89 unilateral partial laminectomy. At follow up the results of the bilaterally operated were all excellent or good whereas 15 per cent with unilateral exposure were unchanged or worse. The unilaterally operated presented a significantly higher incidence of low back pain and recurrence of sciatica than the bilaterally operated. There were no reoperations for recurrent prolapses following the bilateral approach compared with four after unilateral approach. It is concluded that bilateral partial laminectomy affords a good view of the disc pathology and a greater possibility for obtaining relief of the symptoms without reducing the stability of the column.

Key words: lumbar disc prolapse, sciatica, intervertebral disc displacement, surgical approach, unilateral and bilateral partial laminectomy.

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The best surgical approach in lumbar disc prolapse is still a matter for discussion. The communications in the literature vary considerably regarding the operative technique and the results of the operative treatment (Armstrong 1951, Connolly & Newman 1971, Hakelius 1970, O'Connell 1951, Raaf 1970, Rosen 1969, Simeone 1971). No method seems to be generally accepted.

One reason for this great divergence in results may be the preoperative heterogeneity of the various materials. In addition the psychosocial and economic aspects of these lesions play an important and steadily increasing role and have a

perceptible influence on the pre- and postoperative evaluation. Lastly, the diagnostic ability of the surgeon and his surgical skill must be taken into consideration.

Little has so far been reported about different operative methods in prolapse surgery from one department. The purpose of this study is to evaluate the late results of two different exposures, unilateral and bilateral partial laminectomy, especially concerning the relief of sciatica, postoperative low back pain, recurrence of severe sciatica and surgery for recurrent prolapse.

- Takeda T (1975) Three dimensional observation of collagen framework of human lumbar discs *J Jap orthop Ass* 49 45-57
- Thiéry J P (1967) Mise en évidence des polysaccharides sur coupes fines en microscopie électronique *J Microscopie* 6 987-1018
- Watanabe S (1960) Ageing of the human intervertebral disc from the aspect of histochemistry and submicroscopic structure *Shinshu Med J (Japanese)* 9 16-32
- Weiss C (1973) Ultrastructural characteristics of osteoarthritis *F d Proc* 32 1459-1466

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flected to spread the lumbar interlaminar spaces.

The choice of exposure was quite independent of the preoperative symptoms and signs. It only depended upon which method the surgeons, mostly four, experienced either as operators or assistants were accustomed to use.

The surgical indications in our hospital are very restrictive. As a general rule surgical intervention is not considered justified without prior conservative therapy for at least 6 weeks. In addition our department emphasizes the importance of pre- and postoperative treatment with exercises and therefore it is of interest to mention that the mean period of hospitalization was 43 days in both groups.

As can be seen in Figure 1 the sex and age distribution and the mean age at operation were rather similar in the two series.

The statistical analysis between the groups has been performed with the χ^2 test with Yates' correction.

Follow-up examination

All the 156 patients were examined 4-9 years after the operation, partly by personal examination and partly by a questionnaire, the average observation time being 7 years in Group I and 6 years in Group II. Three patients had died from heart disease but sufficient information regarding their previous back disorder was given by the relatives and the postoperative examinations documented in the records.

RESULTS

As indicated in Table 1, there are only minor differences between the groups as regards the preoperative status defined according to various parameters in the clinical history. A similar uniformity regarding the preoperative signs and myelographic findings is documented in Table 2.

II cases

graphie
hypersensitivity to the contrast medium or clinically convincing symptoms. By review of the X-rays of the lumbosacral column no preponderance of general lumbar disc degeneration was displayed in either of the series.

It can be seen from Table 3 that seven cases (8 per cent) in Group II were operated at the L₁/S₁, and the L₂/S₂,

levels. Four had protrusions and two negative findings. The last one was only explored at one level and the discs were judged to be quite normal at the primary operation.

Table 1 Preoperative status in 156 patients with unilateral and bilateral partial laminectomy

	Group I Per cent	Group II Per cent
Type of work		
heavy manual	26	24
manual	40	38
non manual	34	38
Previous low back pain	84	81
Onset of sciatica		
acute	88	47
gradual	44	53
Localisation of sciatica		
right	50	49
left	50	51
Pain on coughing and sneezing	85	89
Duration of symptoms		
0-3 months	47	49
4-6 months	53	51

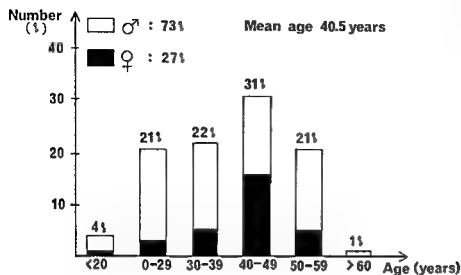
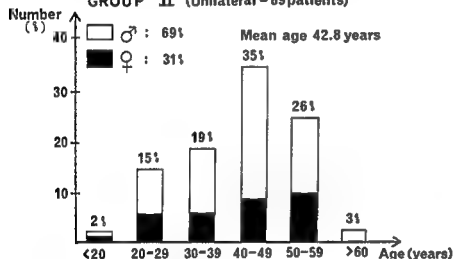
Table 2 Signs and myelographic findings in 156 patients with unilateral and bilateral partial laminectomy

	Group I Per cent	Group II Per cent
Positive Lasègue's sign	97	84
Impaired sensibility	53	66
Impaired Achilles reflex	43	49
Pareses	47	55
Myelography		
positive	95	97
negative	1	1
not performed	3	8

The percentage of free, sequestered prolapses is strikingly high, more so in Group I than in Group II, but the difference is not significant ($P > 0.10$). The designation "extruded prolapse" includes not only a free sequestrum in the spinal canal but also an extruding prolapse through a rupture of the annulus or the posterior longitudinal ligament.

GROUP I (Bilateral-67 patients)

Figure 1 Sex and age distribution of 156 patients with unilateral and bilateral partial laminectomy

**GROUP II (Unilateral-89 patients)****MATERIAL AND METHODS**

During the period 1967-1971, 249 patients were operated for lumbar disc prolapse at Martina Hansens Hospital. In order to get two comparable groups preoperatively with the exposure as the only variable parameter, 156 patients fulfilled the following criteria:

- 1) Maximum of 6 months duration of symptoms after the attack of sciatica which led to the operation
- 2) Unilateral symptoms of sciatica
- 3) Affection of the fifth lumbar and/or the first sacral nerve root
- 4) No previous operation for lumbar disc prolapse or other back disease

Treatment

In Group I 67 patients were treated by bilateral partial laminectomy. The muscles were

detached from the spinous processes and the laminae to the intervertebral joints. About one third of the spinous process facing the intervertebral space was chiselled off and the ligaments removed. The laminectomy was more extensive on the prolapse side, here occasionally including the medial border of the joint facet without destruction of the intervertebral joint. The disc was incised and completely emptied on both sides.

In Group II with 89 patients an interlaminar unilateral exposure was performed with detachment of the muscles and extirpation of the ligaments only on the prolapse side. After minimal removal of the adjacent edges of the laminae, the disc was incised and emptied as completely as possible from one side only.

All the patients were operated on in the prone position with rolls placed under the shoulders and the chest wall and the table usually

Group I were a 48-year-old woman with predominantly psychosocial problems, a 60-year old man with no existing painful hip arthrosis and a 61-year old man with 50 per cent disability. Nevertheless, they stated the results of their operated back as being "good", which was also confirmed by objective examination.

Table 5 Long term effects in 156 patients with unilateral and bilateral partial laminectomy

	Group I Percent	Group II Percent
Low back pain	30	51
Recurrence of severe sciatica	13	26
Returned to work within 1/2 year postoperatively	91	80
Lighter work	12	9
Reduced physical activity	18	40
Disability insurance	4	12

Recurrences

Among the 156 patients six were re-operated during the follow up time. Two surgical explorations for suspected recurrent prolapses in Group I revealed one case with discitis and one with adhesions on the previously prolapsed side.

However three patients in Group II were reoperated for massive, free, sequestered prolapses at the same level and on the same side 1-2 years after the primary exposure. A free sequestrum was also present at the initial operation in two of them. The fourth patient with manifest clinical signs of prolapse was exposed unilaterally at one level in 1967, but the exploration of the last two lumbar spaces failed to provide any explanation for the condition. The decompression of the laminectomy apparently improved the symptoms, but bilateral laminectomy through two levels in 1969 revealed an overlooked sequestered prolapse with adhesions of the 5th and a new extrusion of the 4th disc.

DISCUSSION

The two groups can be compared reasonably well because of their similarity in composition and in the various parameters demonstrated. Therefore, the preponderance of successful results in Group I should indicate a more rational and effective surgical exposure.

However, strong objections can be raised. This is a retrospective study without randomized groups. Moreover, the surgeons have used only their own exposure routinely. Thirdly, a minor preponderance of free extruded prolapses in Group I, even if it is not statistically significant, might point to a more advanced process of degeneration, sequestration and extrusion among these patients. A more "ripe" prolapse is known to give a more successful result (Burns & Young 1951).

On the other hand, it is very doubtful whether the increased incidence of low back pain in Group II can be explained by the higher mean age at operation (23 years) and the longer follow up period (0.9 year). These differences are considered too small to influence the results.

The arguments against the unilateral interlaminar approach are that it affords a poor view and prevents complete emptying of the disc. The importance of complete removal has been pointed out by several authors (Armstrong 1951, Raaf 1970, Rosen 1969). For these reasons a partial bilateral laminectomy should be preferred.

The objection to total laminectomy and to some extent hemilaminectomy is that it produces a reduced postoperative stability of the column, resulting in low back pain (Connolly & Newman 1971). However, Jackson (1971) and Naylor (1974) reported no difference in the incidence of low back pain among patients with wide laminectomy and those with the interlaminar approach.

The bilateral exposure as described in

The peroperative complication frequency in the material is 6 per cent dural ruptures in Group I against 11 per cent in Group II. In addition, late complications included one patient with discitis in the former group and one with spondylitis in the latter group.

Table 3. Disc levels and findings at operation in 156 patients with unilateral and bilateral partial laminectomy

	Group I Per cent	Group II Per cent
Operated disc level		
L 4/I 5	54	50
L 5/S 1	46	42
L 4/I 5 + L 5/S 1	0	8
Findings at operation		
Extruded prolapse	43	33
Protrusion	57	64
Negative	0	3

At follow-up, the state of the patients was classified according to the criteria presented in Table 4, mainly judged from their subjective assessment of functional ability. The bilaterally operated were all

"excellent" or "good" while 15 per cent with unilateral exposure were "unchanged" or "worse". This difference is statistically significant ($P < 0.005$). If only the "excellent" results are taken into consideration the difference is highly significant ($P < 0.001$). In Table 5 the significantly higher incidence of low back pain in Group II ($P < 0.05$) is noteworthy.

In addition, there were nine patients (13 per cent) in Group I and 23 patients (26 per cent) in Group II with recurrences of severe sciatica (Table 5). Whereas 6 and 18 patients in Groups I and II, respectively, had recurrences in the same limb as the initial syndrome, it was interesting to note that only two in Group I as against three in Group II experienced the new attack of sciatica on the opposite side to their previous prolapse. The last three patients reported that they had bilateral recurrences. The designation of an episode of severe sciatica as recurrent sciatica during the follow-up period implies an official sick registration or hospitalization for at least 3 weeks.

The three patients (4 per cent) receiving disability insurance and belonging to

Table 4. Results of follow up examination in 156 patients with unilateral and bilateral partial laminectomy

	Group I Per cent	Group II Per cent	
Excellent			
Symptom free or occasional minimal residual symptoms, normal working ability	64	34	91 per cent satisfactory
Good			
Slight symptoms, full time occupation in lighter work	36	51	
Unchanged			
Significant symptoms, unable to work or doing light work periodically	0	2	9 per cent unsatisfactory
Poor			
Not relieved of major preoperative symptoms or worse postoperatively, disability insurance owing to the back disease	0	11	

Group I were a 48 year old woman with predominantly psychosocial problems, a 60 year-old man with co existing painful hip arthrosis and a 61-year old man with 50 per cent disability. Nevertheless they stated the results of their operated back as being 'good', which was also confirmed by objective examination.

Table 3. Long term effects in 106 patients with unilateral and bilateral partial laminectomy

	Group I Per cent	Group II Per cent
Low back pain	88	91
Recurrence of severe sciatica	13	26
Returned to work within 1/2 year postoperatively	91	80
Lighter work	12	9
Reduced physical activity	18	40
Disability insurance	4	12

Recurrences

Among the 106 patients six were re-operated during the follow-up time. Two surgical explorations for suspected recurrent prolapses in Group I revealed one case with discitis and one with adhesions on the previously prolapsed side.

However three patients in Group II were reoperated for massive free, sequestered prolapses at the same level and on the same side 1-2 years after the primary exposure. A free sequestrum was also present at the initial operation in two of them. The fourth patient with manifest clinical signs of prolapse was exposed unilaterally at one level in 1967 but the exploration of the last two lumbar spaces failed to provide any explanation for the condition. The decompression of the laminectomy apparently improved the symptoms but bilateral laminectomy through two levels in 1969 revealed an overlooked sequestered prolapse with adhesions of the 5th and a new extrusion of the 4th disc.

DISCUSSION

The two groups can be compared reasonably well because of their similarity in composition and in the various parameters demonstrated. Therefore, the preponderance of successful results in Group I should indicate a more rational and effective surgical exposure.

However, strong objections can be raised. This is a retrospective study without randomized groups. Moreover, the surgeons have used only their own exposure routinely. Thirdly, a minor preponderance of free extruded prolapses in Group I, even if it is not statistically significant might point to a more advanced process of degeneration, sequestration and extrusion among these patients. A more 'ripe' prolapse is known to give a more successful result (Burns & Young 1951).

On the other hand, it is very doubtful whether the increased incidence of low back pain in Group II can be explained by the higher mean age at operation (23 years) and the longer follow-up period (0.9 year). These differences are considered too small to influence the results.

The arguments against the unilateral interlaminar approach are that it affords a poor view and prevents complete emptying of the disc. The importance of complete removal has been pointed out by several authors (Armstrong 1951, Raaf 1970, Rosen 1969). For these reasons a partial bilateral laminectomy should be preferred.

The objection to total laminectomy and to some extent hemilaminectomy is that it produces a reduced postoperative stability of the column, resulting in low back pain (Connolly & Newman 1971). However, Jackson (1971) and Naylor (1974) reported no difference in the incidence of low back pain among patients with wide laminectomy and those with the interlaminar approach.

The bilateral exposure as described in

the present study by no means implies such an extensive procedure as a total or hemilaminectomy. The anatomy of the spinal column presents great individual variations, especially in the width and the position of the laminae. In some patients the interlaminar space, particularly at the L₅/S₁ level, is sufficiently wide to permit removal of the protruding intervertebral disc with minimal bilateral excision of bone.

The incidence of recurrent herniations at the same or another level reported in the literature varies between 0 per cent and 24 per cent with an average of 10 per cent (Stauffer et al 1971). In the present series the rate amounts to scarcely 2 per cent, and the only overlooked prolapse and the three recurrent prolapses at the same level were seen among the unilaterally exposed patients.

Recurrence at the level of the original prolapse is probably due to continuation of the biochemical, degenerative process resulting in a loose sequestered nucleus or annulus fragment. Considerable degenerated tissue may be present, and after withdrawal of a free sequestrum or a bulging disc a radical removal of the interspace from both sides and across the midline with a conchotome is indicated. Lastly, a curettage is performed leaving only the anterior and lateral rims of the annulus intact. We have also found it valuable to record routinely the weight of the disc tissue removed at operation. At the follow up examination this figure tells something of how radical the previous disc excision was.

The follow-up gives the impression that the bilateral partial laminectomy is a more valuable and safe procedure than the unilateral one, which perhaps may be insufficient in a given case. The better

exposure affords a good view of the pathology and a greater possibility for ensuring relief of the symptoms. Bilateral exploration does not seem to induce an increased postoperative morbidity or to influence the integrity or the stability of the spinal column to any great extent. Our material indicates that postoperative adhesions with severe sciatica contra laterally to the previous prolapse rarely occur among bilaterally exposed patients.

REFERENCES

- Armstrong J R (1951) The causes of unsatisfactory results from the operative treatment of lumbar disc lesions. *J Bone Jt Surg* 33 B 31-35.
- Burns D H & Young R H (1961) Results of surgery in sciatica and low back pain. *Int J Orthop* 1 245-249.
- Connolly, R C & Newman, P H (1971) Lumbar spondylotomy. *J Bone Jt Surg* 53 B 575-577.
- Hakelius A (1970) Prognosis in sciatica. A clinical follow up of surgical and non surgical treatment. *Acta orthop scand* Suppl 129.
- Jackson R K (1971) The long term effects of wide laminectomy for lumbar disc excision. *J Bone Jt Surg* 53 B 609-616.
- Naylor A (1974) The late results of laminectomy for lumbar disc prolapse. A review after ten to twenty five years. *J Bone Jt Surg* 56 B 17-29.
- O'Connell J I A (1951) Protrusions of the lumbar intervertebral discs. A clinical review based on five hundred cases treated by excision of the protrusion. *J Bone Jt Surg* 33 B 31-35.
- Raaf J (1970) Removal of protruded lumbar intervertebral discs. *J Neurosurg* 32 604-611.
- Rosen H J (1969) Lumbar intervertebral disc surgery. Review of 300 cases. *J Canad med Ass* 101 317-323.
- Simeone I A (1971) The neurosurgical approach to lumbar disc disease. *Orthop Clin N Amer* 11 499-506.
- Stauffer R V, Evans J C & Miller R H (1971) The lumbar disc syndrome and its operative treatment. *Postgrad Med* 49 87-93.

POSTERIOR VERSUS LATERAL APPROACH FOR HIP ARTHROPLASTY

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In a study of two groups of 100 patients each with a similar composition (age, sex and indications for surgery) operations for total hip arthroplasty took half as long and the blood loss was clearly less when using the posterior route in one group compared with Charnley's conventional approach in the other group. These are important considerations for elderly patients with a high operative risk. Radiologic assessments showed that with the posterior approach there was a wider variation in the location of the cup in the frontal plane. However, this has not caused any inconvenience during the short observation period to date. No comparison has been made of the functional results over an extended period.

Key words: hip surgery, total hip replacement, surgical approach, bleeding and hip surgery.

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Major advances in hip surgery have been achieved during the last two decades chiefly through the work of Charnley (1972). His operative method with a lateral approach and trochanteric osteotomy is generally accepted but many surgeons have found that it takes a long time (Thompson & Culver 1973, Sculco & Kanawalt 1973, Koide et al 1974).

The present retrospective study concerns 100 patients who underwent total hip arthroplasty via posterior incision and 100 having the same operation via a lateral incision as described by Charnley. The two groups were compared with respect to the duration of the operation, the amount of blood transfused, the operative complications and the position of the acetabular cup in a frontal radiographic projection.

PATIENTS AND METHODS

An analysis of the two groups of patients according to age and sex is given in Table 1. The indication for surgery was osteoarthritis, rheumatoid arthritis or persistent disability after fracture of the femoral neck or acetabulum (Table 2). Cases of infection after earlier prosthetic surgery were excluded but the groups do contain patients with no signs of infection after an earlier Judet or Moore prosthesis.

The 100 patients in one group were operated on with one of the approaches at the Department of Orthopaedics at Gävle Hospital during the period May 1973 to December 1974 and the other approach was used in 100 patients at the Department of Orthopaedics at Falun Hospital during the period January to December 1974.

The posterior approach was undertaken largely as described by Lebusius & Jacobsen (1973). The incision ran laterally over the proximal femoral shaft and then curved away in a dorsal direction. Fascia lata and gluteus maximus were split along the fibres. The short rotator muscles

were cut and were not re sutured. The femur was cut through at the neck after dislocation which only occasionally required the prior removal of osteophytes from the acetabular rim. The patient lay straight on one side and the cup was positioned in about 15-20° anteroversion at an angle of 40-45° in the frontal plane. The operation was performed with the Brunswick instrumentarium.

Table 1 Mean age and sex distribution in the two groups

	Posterior approach	Trans-trochanteric approach
Mean age	66 years	66 years
Men/women	48/52	46/54

Table 2 Indications for the operation

	Posterior approach	Trans-trochanteric approach
Osteoarthritis	90	91
Rheumatoid arthritis	9	9
Persistent disability after fracture	11	10

In the Charnley group the patient was supine. A lateral incision was made and the trochanter was cut with a Gigli saw. The acetabulum was ground out fairly extensively and the cup was positioned at an angle of about 45° in the frontal plane but with no antero- or retroversion. In keeping with Charnley's basic principles attempts were made to lateralize and distalize the trochanter when making re attachment, the aim being to increase the leverage of the gluteal muscles. The instruments advocated by Charnley were used.

Antibiotics were administered prophylactically in both groups (Cloxacillin 4 g daily for 1 week starting on the morning of the operation).

The operations with the posterior approach were performed by one of four surgeons (of whom three were senior surgeons) whilst ten surgeons (five of them senior) were involved in the Charnley group.

A neuroleptic anaesthesia (Pavulon Leptanal) was used in all cases with the posterior approach while epidural anaesthesia predominated in the lateral group.

The total amount of blood transfused was

compared in the two groups instead of studying the degree of pre- and postoperative bleeding. The indications for transfusion appear to have been similar in the two hospitals (subjective and objective hypovolaemia, haematocrit below 30) and therefore this amount should give a comparable picture of the total blood loss.

Postoperative dislocation has been included in the comparison if it could be demonstrated radiologically but not if it was only subjective partial dislocation or a feeling of dislocation upon flexion medial or lateral rotation of the hip.

The position of the acetabular cup has been measured only in the frontal plane. This was done by a radiologist for a random sample of 30 patients in each group. The angle between the cup and a line joining the two tubercles was calculated. It would have been desirable to assess the position of the cup in a lateral projection too but no X rays of this projection were available for many of the patients in the Charnley group.

Prophylactic treatment for thrombosis was given in conjunction with the posterior approach, only in the form of Iohman bandings on the leg postoperatively and oxiphenbutazon 0.1 g \times 3 in the Charnley group. Every patient received Macrodex prophylactically for thrombosis (500 ml on the day of the operation followed by 500 ml on the 3rd and 5th days postoperatively).

The patients have been followed for at least 1 year after the operation.

RESULTS

The average duration of the operation and the amount of blood transfused are shown in Table 3. Even when the comparison is confined to operations performed by senior surgeons, the difference in average duration is still considerable (55 and 112 minutes, respectively).

Table 3 Average duration of operation and amount of blood transfused per and postoperatively

	Posterior approach	Trans-trochanteric approach
Duration of operation	55 min	122 min
Blood transfused	650 ml	1600 ml

Blood loss as reflected by the amount transfused pre- and postoperatively, is clearly smaller with the posterior approach. In this group, moreover, no blood transfusion at all was required in 28 cases compared with only one case with the lateral approach.

A comparison of major complications noted in the case records is given in Table 4.

Table 4 Complications

	Posterior approach	Trans trochanteric approach
Death	1	0
Sciatic paresis	3	1
Dislocation	1	1
Deep infection (suspected)	1	1
Haematoma	1	0
Infarct	(1 fatal)	1
Thrombosis	1	7
Pulmonary embolism	0	4
Slight trochanter problem	0	2

The operative technique caused no problems in either group. In one case in the Brunswick material, however, the shaft of the prosthesis perforated the femur; reoperation gave a satisfactory result.

The position of the cup in the frontal plane resulted in an average angle of 43° for patients in the Brunswick group and 44° for those with the lateral approach. As shown in Figure 1, however, the posterior approach gave a wider dispersion around the mean.

DISCUSSION

The trans trochanteric approach used to be and in many places still is the conventional route for total hip arthroplasty. However, as this operation takes rather a long time and problems are encountered with the trochanter (Lubinus & Jacobsen 1973, Buchholz & Noach 1973, Thompson & Culver 1975), many authors

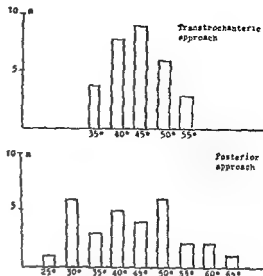


Figure 1 Distribution of the cup position in the frontal plane determined radiographically

prefer other surgical incisions, such as those described earlier by Kocher (1911) and Osborne (1930). With the posterior approach, an operation with the Brunswick prosthesis is reported by Lubinus & Jacobsen (1973) to take an average of 50 minutes, whereas with the trans trochanteric route it takes more than 2 hours (Thompson & Culver 1975, Sculco & Ranawat 1975, Koide et al 1974).

The two groups which are compared in the present study have practically identical distributions as far as sex, age and indications for the operation are concerned. The clear, statistically significant differences which have been found between them in the duration of the operation and the blood loss must be regarded as of major importance, considering that this type of operation is performed as a rule in old patients with a high operative risk. Apart from the approach and the surgeons involved, the two groups differ in principle only in the type of anaesthesia. Total arthroplasty with epidural anaesthesia gives a lower blood pressure during the operation and a smaller loss of blood (Jacobson & Wigren 1972, Sculco & Ranawat 1975), in addition to

the shorter duration (Sculco & Ranawat 1975). With the same type of anaesthesia, the difference between the groups would therefore presumably be still more marked. Whether Macrodex given prophylactically for thrombosis should cause more bleeding in the Charnley group is difficult to say.

In the present group with the lateral approach, the trochanter posed no problems, in contrast to other studies (Weaver 1975, Thompson & Culver 1975). Neither was postoperative dislocation any problem in either of the groups studied. The single instance in the transtrochanteric group occurred 40 days after the operation, the joint was reduced and the patient has been free from symptoms ever since. The only dislocation with a Brunswick prosthesis occurred in the second postoperative month, traction therapy was given for 4 weeks and the patient was free from symptoms at follow-up one and a half years after the operation. In this case the position of the cup in the frontal plane was acceptable but a lateral projection showed 5–10° retroversion, which may have contributed to the dislocation.

It is commonly considered that dislocation after hip arthroplasty occurs more frequently with the posterior approach. However, in a survey of late results of 1850 Brunswick prostheses with this approach, Lubinus (1973) found only five dislocations, which is one of the lowest figures for a large material of total hip replacements. This may be due to the greater depth of the Brunswick cup compared with Charnley's, as well as to its larger head on the shaft and its position with about 20° anteversion. With the transtrochanteric approach and Charnley's instruments, the frequency of dislocation in several other reports is relatively high: three dislocations after 100 operations (Dall 1975), six after 126 (Thompson & Culver 1975) and, from Sweden, 13 after 283 (Bergstrom et al

1973). Charnley (1973) himself had six dislocations among 185 patients followed for 9–10 years.

Many factors would seem to contribute to a dislocation. Lubinus (1973) mentions the position of the cup, retro- or anteversion of the prosthetic shaft and the length of its neck. In the present group with the posterior approach, the position of the cup in the frontal projection showed a definitely wider variation radiographically. It is possibly somewhat more difficult to site the cup correctly when the patient is in a lateral rather than a supine position. In the same way as Lubinus (1973), we have found that with experience it is not difficult to ensure the correct position of the cup with the posterior approach.

The death in the group with the posterior approach concerned a man of 73 with heart disease. The operation took 45 minutes and the patient lost 300 ml of blood. He died on the 4th postoperative day and autopsy revealed old as well as fresh cardiac infarcts but no sign of pulmonary embolism.

There were more cases of sciatic palsy after the posterior approach but none of the four patients in the two groups combined required bandaging on the account at the follow-up examination. This paresis disappears as a rule within 1–4 months (Lubinus & Jacobsen 1973) and its frequency with the posterior approach is reported to be about 1 per cent.

One case of suspected deep infection has been noted in each group. Both patients had a persistently high ESR 1 year after the operation but no radiographic or subjective symptoms of infection. The observation time is too short and the number of cases too small to warrant further discussion of this parameter.

In the case of venous thrombosis and pulmonary embolism, the diagnostic criterion is of major importance and may have differed between the two groups. However, one cannot ignore the possibil-

ity that the higher frequency of pulmonary embolism in the transtrochanteric group and perhaps even the seven cases of calf thrombosis had to do with the longer duration of the anesthesia and the operation.

The operative technique did not cause any problems in either group. We were unable to confirm the opinion of Thompson & Culver (1975) that the posterior approach is less suitable for patients with malposition of the hip in lateral rotation.

REFERENCES

- Bergstrom B, Lindberg L, Persson B M & Önerfält R (1973) Complications after total hip arthroplasty according to Charnley in a Swedish series of cases. *Clin Orthop* 90: 91-95.
- Buholte H W & Noack G (1973) Results of the total hip prosthesis design "St George". *Clin Orthop* 90: 201-210.
- Charnley J (1972) The long term results of low friction arthroplasty of the hip performed as a primary intervention. *J Bone Jt Surg* 54 B: 61-76.
- Charnley J & Cupic Z (1973) The nine and ten year results of the low friction arthroplasty of the hip. *Clin Orthop* 93: 9-25.
- Dall D M (1975) Charnley hip replacement: early results. Proceedings and reports. *J Bone Jt Surg* 57 B: 259.

- Jacobson S & Wigren A (1972) Epidural anæstesi och blodning vid stor höftkirurgi. *Scenska Läk Tidn* 69: 277-279.
- Kocher T (1911) *Textbook of operative surgery*. 3rd ed. A and Ch Black, London.
- Koide M, Pilon R V, Vandam L B & Lowell J H (1974) Anesthetic experience with total hip replacement. *Clin Orthop* 99: 18-30.
- Lubinus H H (1973) Total hip replacement using the Brunswick system. *Clin Orthop* 93: 211-219.
- Lubinus H H & Jacobsen U (1973) Erfahrungen mit dem totalen Hüftersatz unter Verwendung des Systems Brunswick und eines dorsolateralen Zugangs. *Der totale Hüftgelenkersatz* p. 92-107. Georg Thieme Verlag, Stuttgart.
- Moore A T (1939) The Moore selflocking vitalium prostheses in fresh femoral neck fractures. A new low posterior approach (The southern exposure). American Academy of Orthopedic Surgeons. Instructional course lectures No 16. The C V Mosby Co, St Louis.
- Osborne R P (1930-1931) The approach to the hip joint: a critical review and a suggested new route. *Brit J Surg* 18: 49-53.
- Sculco T P & Ranawat C (1975) The use of spinal anesthesia for total hip replacement arthroplasty. *J Bone Jt Surg* 57 A: 173-177.
- Thompson R C & Culver J F (1975) The role of trochanteric osteotomy in total hip replacement. *Clin Orthop* 106: 102-106.
- Weaver J K (1975) Total hip replacement: A comparison between the transtrochanteric and posterior surgical approach. *Clin Orthop* 112: 201-207.

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THE USE OF BONE CEMENT AS AN ADJUNCT TO INTERNAL FIXATION OF SUPRACONDYLAR FRACTURES OF OSTEOPOROTIC FEMURS

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Bone cement was used as an adjunct to internal fixation of 14 supracondylar femoral fractures. The fractures were stabilized with ASIF plates. In all these fractures severe osteoporosis made a stable fixation impossible without the use of bone cement. The average age of the patients was 75 years. Eight of the patients had previously been operated on because of fractures of the same extremity and three suffered from disabling diseases. Twelve fractures healed without complications, despite early mobilization. One fracture needed additional external fixation before it healed and one led to non union. No infections were seen. It is concluded that use of bone cement as an adjunct to the internal fixation of supracondylar fractures secures a stable fixation of even the most severe osteoporotic femora and thus aids healing in most cases of such fractures. The method is recommended in selected cases of elderly patients.

Key words: internal fixation, supracondylar femoral fracture, bone cement

Accepted 15 x 76

Until a few years ago conservative treatment was considered superior to internal fixation of supracondylar femoral fractures in adults (Stewart et al 1966, Neer et al 1967). However, the development of new fixation devices and techniques has, according to several investigations, improved the results of the treatment of these fractures. Thus, the use of the ASIF-condylar plates, as suggested by Muller et al (1965) in most cases secures a stable fixation of an ideally reduced fracture and makes early mobilization possible, resulting in excellent or satisfactory results (Slatis et al 1971, Olerud 1972, Chiron et al 1974). Nevertheless, in supracondylar fractures of severe

osteoporotic femora there are still problems in obtaining a stable fixation.

The use of bone cement as an adjunct to internal fixation of fractures, as suggested by Muller (1962), may also be applied in the treatment of supracondylar fractures of the severely osteoporotic femur. In our department, bone cement has been used as adjunct to internal fixation in such fractures since 1968. The purpose of this paper is to present the results of the method.

PATIENTS AND METHODS

There were 14 female patients with fractures through the supracondylar region of the femur without affection of the knee joint. Severe

Case	Age (yr)	Type of fracture	Previous disease or operatively treated fracture	Healing time in months	Walking function		Axis
					Before injury	After healing	
1	85	Transverse comminuted	Hemiplegia	2½	10 months	Confined to bed	Recurvation 10 degrees
2	74	Oblique comminuted	Coxarthrosis	Non union	16 months	1 stick	Normal
3	82	Oblique comminuted	Polyarthritia	3	6 years	Confined to bed	Recurvation 5 degrees Varus 5 degrees
4	63	Transverse comminuted	None	4½	6 years	No aids	Valgus 5 degrees
5	74	Short oblique	Tibial shaft fracture Tibial condylar fracture	4½	3 years	No aids	Normal
6	84	Transverse	Femoral neck fracture Supracondylar femoral fracture	4	7 months	No aids	Valgus 5 degrees
7	84	Long oblique	None	4	4 years	No aids	Varus 15 degrees
8	71	Long, oblique	Femoral neck fracture	3	8 months	2 crutches	Normal
9	68	Short, oblique	None	4	5 years	No aids	Normal
10	82	Oblique, comminuted	Femoral neck fracture	3	4 months	Confined to bed	Normal
11	71	Long, oblique	Femoral neck fracture (nailed, femoral head prosthesis, total hip prosthesis) Femoral shaft fracture	4	14 months	2 crutches	Normal
12	70	Transverse	Tibial condylar fracture	3	18 months	No aids	Normal
13	71	Transverse	Femoral neck fracture (nailed, Cyp-a pl) Supracondylar femoral fracture	4	10 months	2 crutches	Normal
14	75	Long	Femoral neck fracture (nailed, femoral head prosthesis, total hip prosthesis)	4	5 months	2 crutches	Recurvation 5 degrees



Figure 1 A and B Radiographs of a supracondylar femoral fracture (Case no 8 Table 1) The pictures demonstrate a severe osteoporosis in the supracondylar region



Figure 1 E and F Radiographs 3 months after operation The lateral view reveals that the fracture has been bridged by bone posteriorly There is no abundant periosteal callus formation No signs of loosening of the screws are seen The axes are unchanged from the first postoperative examination (compare with Figure 1 C and D)

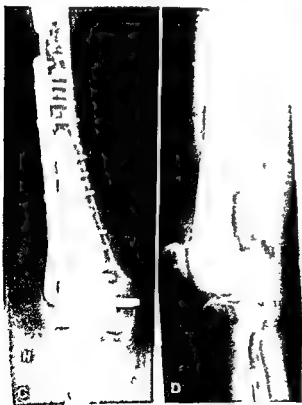


Figure 1 C and D Postoperative radiographs The intramedullary cavity is filled with bone cement The condylar plate has been fixed with screws through the implanted cement

osteoporosis was found during operation in all these patients. The degree of osteoporosis was so severe that fixation by plates and screws was insufficient without adjunctive use of bone cement. Eight of the patients had previously been operated on for fractures of the same extremity, three suffered from disabling diseases of the locomotor system while three suffered from osteoporosis only. Their ages varied from 58 to 92 years with an average of 75 years. The relevant data are given in detail in Table 1. The total number of patients admitted for supracondylar femoral fractures in the corresponding age group was 57, only seven of these were treated conservatively.

Operation method

The fractures were all operated on according to the ASIF principles using condylar plates (Muller et al 1965) except in one case where a straight plate was used. The fractures were reduced and a channel for the blade of the plate was prepared with a special chisel. Bone cement

(Simplex P) of a doughy consistency was packed into the medullary cavity and the blade of the plate was inserted before the cement had cured. If there was not a considerable defect at the fracture site due to comminution of the fracture the fracture had to be redislocated in order to install the cement. Subsequently the fracture was finally reduced. Attempts were made to place the cement strictly intramedullarily. After the cement had cured holes were drilled through the bone and the cement the holes were tapped and the cortical screws were fastened giving a firm attachment of the plate to the femur. One example of an operated fracture is shown in Figure 1.

The operations were performed without sterile enclosure. Prophylactic antibiotics were not used.

Postoperative treatment

The patients were generally kept in bed for a couple of days, the knee of the operated leg being immobilized in a semiflexed or ninety degrees flexed position by use of a splint. Walking exercises were then started, the patients using a walkerette and later crutches. Only partial weight bearing was allowed until the fracture was found to be consolidated.

RESULTS

The results were examined by clinical and radiological investigations at varying intervals. The length of the follow-up periods varied from 3 months to 8 years. Details are given in Table 1.

One patient died of pneumonia after reoperation for non union (case no. 2). The fractures of all the other patients healed from 3 to 5 months after operation. All these fractures healed without change of the axis established at the operation except one which had to have a plaster cast for two months following redislocation of the fracture two months postoperatively (Case no. 7). Some of the other fractures healed with slight angulation; this was due to inaccurate reposition and not to failure of the fixation. There were no refractures. Post-osteal bone formation was rather scanty in most of the fractures (Figure 1).

No exact information can be given

about the influence of the fracture on the mobility of the knee joint, most of the patients had a reduced mobility of the knee even before they sustained their supracondylar fracture. The walking function after healing of the fracture was in most patients slightly or moderately impaired.

DISCUSSION

The material presented represents the most unfavourable cases of supracondylar femoral fractures in a group of elderly patients. All the patients suffered from severe osteoporosis and impaired walking function due to previously sustained fractures of the same extremity or to disabling diseases. The findings at the operations revealed that stable fixation was impossible without the use of bone cement. Hence, the results cannot be compared with results obtained in unselected materials.

The fact that 12 of the 14 fractures healed without changes of alignment after 3 to 5 months despite early mobilization shows that supracondylar fractures even in the presence of severe osteoporosis are likely to heal when bone cement is used as an adjunct to adequately placed ASIF plates. It is worth noting that the failures of fixation, one leading to non-union and one necessitating additional external fixation, were due to technical errors in the application of the plates and not to loosening of the screws from the bone cement itself.

According to Cameron et al. (1975), the strength of the cement screw complex is significantly higher when the screws are pushed into soft cement than when the screws are fixed after drilling and tapping in cured cement. However, the latter method which was employed in the present study proved reliable for securing a firm fixation in the severely osteoporotic femur.

The application of bone cement did



Figure 1 A and B Radiographs of a supracondylar femoral fracture (Case no 8 Table 1) The pictures demonstrate a severe osteoporosis in the supracondylar region



Figure 1 E and F Radiographs 3 months after operation The lateral view reveals that the fracture has been bridged by bone posteriorly There is no abundant periosteal callus formation No signs of loosening of the screws are seen The axes are unchanged from the first postoperative examination (compare with Figure 1 C and D)

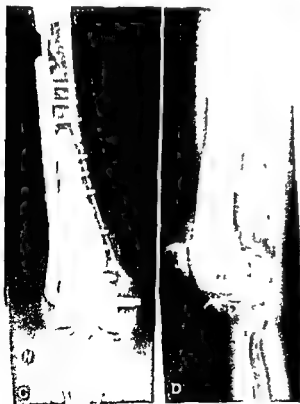


Figure 1 C and D Postoperative radiographs The intramedullary cavity is filled with bone cement The condylar plate has been fixed with screws through the implanted cement

osteoporosis was found during operation in all these patients. The degree of osteoporosis was so severe that fixation by plates and screws was insufficient without adjunctive use of bone cement. Eight of the patients had previously been operated on for fractures of the same extremity, three suffered from disabling disease of the locomotor system while three suffered from osteoporosis only. Their ages varied from 58 to 92 years with an average of 75 years. The relevant data are given in detail in Table 1. The total number of patients admitted for supracondylar femoral fractures in the corresponding age group was 57, only seven of these were treated conservatively.

Operation method

The fractures were all operated on according to the ASIF principles using condylar plates (Muller et al 1965) except in one case where a straight plate was used. The fractures were reduced and a channel for the blade of the plate was prepared with a special chisel. Bone cement

OSTEOSYNTHESIS OF MEDIAL FRACTURES OF THE FEMORAL NECK BY SLIDING NAIL-PLATE FIXATION

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Sliding nail plate osteosynthesis of displaced medial fractures of the femoral neck was carried out in 65 consecutive cases. The appliance presented here differs from other sliding nail plates as it has no fixed angle between the nail and the plate. Immediate postoperative weight bearing was permitted. The average follow up period was 22 years. Union of the fractures was seen in 74 per cent and avascular necrosis in 21 per cent. Complications were few, which we attribute to the early mobilization of the patients.

Key words: early weight bearing, medial fractures of the femoral neck, sliding nail plate osteosynthesis.

Accepted 22 XI 76

In patients with displaced medial fractures of the femoral neck, an osteosynthesis sufficiently solid to permit immediate weight bearing, is desirable but of course without increasing non union or avascular necrosis.

It is generally agreed that in medial fractures of the femoral neck, full reduction of the fracture and rigid apposition of the fracture surfaces are of particular importance, but there is no agreement as to which sort of internal fixation satisfies these aims best.

Sliding nail plate osteosynthesis was earlier reported by Pugh (1955), Massie (1958) and Brown & Abrams (1964). The purpose of this study is to present the findings of a consecutive series of 65 displaced medial fractures of the femoral neck treated with sliding nail plate osteosynthesis and with immediate postoperative weight bearing.

MATERIAL AND METHODS

This study includes all patients with displaced medial fractures of the femoral neck treated in the Orthopaedic Department Ø Odense University Hospital between March 1972 and March 1974. There were 65 patients: 51 women and 14 men. The average age was 74.1 years, ranging from 48 years to 93 years. The age distribution is given in Table 1.

The fractures have been divided according to Garden's (1961) classification: Stage 1, incomplete fracture (impacted valgus fracture); Stage 2, complete fracture without displacement; Stage 3, complete fracture with partial displacement; Stage 4, complete fracture with full displacement.

Only fractures in stage 3 and stage 4 have been considered in this series. Pathological fractures have been excluded.

Operation was performed at the first opportunity but not as an emergency. After admission to hospital, 16 patients were operated within 24 hours, 10 patients between 24 hours and 48 hours and 13 patients between 48 hours and 72 hours. On admission to hospital, traction (usually without internal rotation) was applied through the tibial tubercle. Final adjustment of

not seem to prevent the process of healing. This might be due to the efforts of confining the bone cement to the medullary cavity. Similar findings have been made when bone cement has been used in the upper end of the femur in the stabilization of intertrochanteric fractures (Harrington 1975). On the other hand, no abundant periosteal bone formation could be seen as an effect of the use of bone cement. This is in contrast to what was seen when bone cement was used in intertrochanteric fractures (Harrington 1975).

In some cases it was difficult to assess radiologically the exact extent of the fracture healing, since some parts of the fracture space were hidden by the applied cement. However, the fact that there were no cases of refracture indicates that firm osseous healing really occurred. It seems unreasonable that the fractures should remain stabilized only because of the internal fixation itself. However, it should be noted that not all the operated limbs were exposed to maximal weight-bearing. Most of the patients used some walking aids, partly because they were more or less disabled before they sustained their supracondylar femoral fracture.

Even though there were no cases of postoperative wound infections in the present series, the risk of this complication must not be neglected since infection after use of bone cement might be disastrous to the end result. On the other hand, if stable internal fixation is not obtained, this may lead to delayed union or non-union. Unstable internal fixation of supracondylar femoral fractures also implies a greater risk of infection (Stewart et al 1966, Neer et al 1967). Occasionally, inadequate fixation may even lead to a combination of complications necessitating amputation of the limb (Haukebo 1976).

When severe osteoporosis is present

traction treatment might be an alternative method to internal fixation with adjunctive use of bone cement. However, traction treatment includes the risks of general complications of long-lasting immobilization of elderly patients and necessitates a prolonged stay in a surgical unit.

Taking account of these considerations and the results of the operations it seems advisable to recommend the adjunctive use of bone cement for internal fixation of supracondylar fractures of the severely osteoporotic femur in elderly patients.

REFERENCES

- Cameron, H U, Jacob C B R, Macnab, I & Pilliar, R M (1975) Use of polymethyl methacrylate to enhance screw fixation in bone. *J Bone Jt Surg* 57 A, 655-656.
- Chiron H S, Tremoulet, J, Casey, P & Muller M (1974) Fractures of the distal third of the femur treated by internal fixation. *Clin Orthop* 100 160-170.
- Harrington K H (1975) The use of methyl methacrylate as an adjunct in the internal fixation of unstable comminuted intertrochanteric fractures in osteoporotic patients. *J Bone Jt Surg* 57 A 744-750.
- Haukebo A (1976) Personal communication.
- Muller M F (1962) Die Verwendung von Kunstharzen in der Knochenchirurgie. *Arch Orthop Unfall chir* 54 513-522.
- Muller, M F, Allgower, M & Willenegger, H (1965) *Technique of internal fixation of fractures*. Springer Verlag Berlin Heidelberg New York.
- Neer C S, Grantham S A & Shelton M I (1967) Supracondylar fractures of the adult femur. A study of one hundred and ten cases. *J Bone Jt Surg* 49 A 591-613.
- Olerud S (1972) Operative treatment of supracondylar condylar fractures of the femur. Technique and results in fifteen cases. *J Bone Jt Surg* 54 A 1015-1032.
- Slatis P, Roppy S & Huittinen A M (1971) AOI osteosynthesis of fractures of the distal third of the femur. *Acta orthop scand* 42 162-172.
- Stewart M J, Sisk D S & Wallace S I Jr (1966) Fractures of the distal third of femur. A comparison of methods and treatment. *J Bone Jt Surg* 48 A 784-807.



anteroposterior position



lateral position

Figure 9 Radiographs of the sliding nail plate in a femoral neck fracture

3. Doubtful union At the follow up there were two patients (3 per cent) with no clear evidence of bone union but there were no signs of failure either.

Avascular necrosis was seen in seven patients (21 per cent) who had all previously shown bone union. Union was found in stage 3 fractures in 94 per cent and in stage 4 fractures in 61 per cent (Table 2).

In 39 cases with good reduction of the fracture 70 per cent united (Table 3). In 26 cases with good position of the sliding nail 92 per cent united (Table 4).

Postoperative complications were found in 21 patients as listed in Table 5. In one

case we had to remove the appliance one year after the operation because of a deep infection. There were no signs of phlebotrombosis or pulmonary embolism. Prophylactic anti coagulation was not used in the series.

In 10 cases the osteosynthesis failed. Two cases showed poor reduction of the fracture as well as a poor position of the sliding nail. Within the first three months another two patients had a new trauma with redisplacement of the fracture. In a further two cases the sliding nail telescoped out of the femoral head and in three patients no obvious explanation was found.

In the last of the failures the femoral head tilted when the nail was inserted

Table 1 Age distribution of 65 patients with medial fracture of the femoral neck and number of deaths before the follow-up

Age	40-49	50-59	60-69	70-79	80-89	90-	Total
Number of patients	1	4	15	16	21	8	65
Number of deaths before follow up	-	-	1	2	7	2	12

the reduction was made under general anaesthesia on the fracture table with fluoroscopy and image intensifier.

The appliance which is illustrated in Figure 1 consists of a partial trifin nail sliding in a circular barrel. The telescopic property of the nail allows progressive impaction as resorption occurs at the fracture site, without any risk of the nail penetrating the articular surface of the

femoral head. The compressed nail is inserted over a guide pin, and with a special driver the trifin nail is driven into position to 0.5 cm below the articular surface of the femoral head. The nail should be placed at as steep an angle as possible resting on the femoral calcar and a little posterior and inferior to the centre of the femoral head. Lastly, the nail is connected to a three hole plate by a topbolt (Figure 2a and b).

In the postoperative treatment we aimed at an early mobilization. If there were no contra-indications the patient would sit in a chair the day after the operation, and on the second or third day, the patient was permitted to walk with elbow crutches. Weight bearing on the operated leg up to the threshold of pain was allowed. The patients have been followed with clinical and radiographic examination until either union of the fracture or failure was manifest.

At the follow-up 12 (18 per cent) patients had died. Six patients refused to come to hospital for radiographic examination and one patient was an American tourist. They have all been excluded from the results. In the remaining 46 patients clinical and radiographic examinations were made at the follow-up. The average follow-up period was 2.2 years ranging from 1.2 years to 3.5 years.

RESULTS

The results were divided into three groups.

- 1 Union was seen in 31 patients (74 per cent), and this implies bone union of the fracture with radiographic visible trabeculation across the fracture line.
- 2 Failure was seen in 10 patients (22 per cent). This implies recurrence of the fracture deformity. This group also includes two cases of failure of the appliance. This group does not include avascular necrosis.

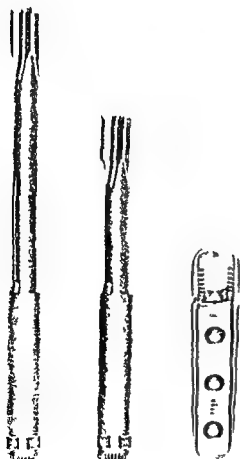


Figure 1 The sliding nail plate material. The nail component is shown in its longest and shortest position.



a anteroposterior position



b lateral position

Figure 2 Radiographs of the sliding nail plate in a femoral neck fracture

3. Doubtful union At the follow up there were two patients (3 per cent) with no clear evidence of bone union but there were no signs of failure either.

Vascular necrosis was seen in seven patients (21 per cent) who had all previously shown bone union. Union was found in stage 3 fractures in 94 per cent and in stage 4 fractures in 61 per cent (Table 2).

In 35 cases with good reduction of the fracture 76 per cent united (Table 3). In 26 cases with poor position of the sliding nail 82 per cent united (Table 4).

Postoperative complications were found in 21 patients as listed in Table 3. In one

case we had to remove the appliance one year after the operation because of a deep infection. There were no signs of phlebotrombosis or pulmonary embolism. Prophylactic anti-coagulation was not used in the series.

In 10 cases the osteosynthesis failed. Two cases showed poor reduction of the fracture as well as a poor position of the sliding nail. Within the first three months another two patients had a new trauma with redisplacement of the fracture. In a further two cases the sliding nail telescoped out of the femoral head and in three patients no obvious explanation was found.

In the last of the failures the femoral head tilted when the nail was inserted

Table 1 Age distribution of 65 patients with medial fracture of the femoral neck and number of deaths before the follow up

Age	40-49	50-59	60-69	70-79	80-89	90-	Total
Number of patients	1	4	15	16	21	8	65
Number of deaths before follow up	-	-	1	2	7	2	12

the reduction was made under general anaesthesia on the fracture table with fluoroscopy and image intensifier.

The appliance which is illustrated in Figure 1 consists of a partial trifin nail sliding in a circular barrel. The telescopic property of the nail allows progressive impaction as resorption occurs at the fracture site, without any risk of the nail penetrating the articular surface of the

femoral head. The compressed nail is inserted over a guide pin, and with a special driver the trifin nail is driven into position to 0.5 cm below the articular surface of the femoral head. The nail should be placed at as steep an angle as possible, resting on the femoral calcar and a little posterior and inferior to the centre of the femoral head. Lastly, the nail is connected to a three hole plate by a topbolt (Figure 2a and b).

In the postoperative treatment we aimed at an early mobilization. If there were no contra-indications, the patient would sit in a chair the day after the operation and on the second or third day, the patient was permitted to walk with elbow crutches. Weight bearing on the operated leg up to the threshold of pain was allowed. The patients have been followed with clinical and radiographic examination until either union of the fracture or failure was manifest.

At the follow up 12 (18 per cent) patients had died. Six patients refused to come to hospital for radiographic examination and one patient was an American tourist. They have all been excluded from the results. In the remaining 46 patients clinical and radiographic examinations were made at the follow up. The average follow up period was 2.2 years ranging from 12 years to 35 years.

RESULTS

The results were divided into three groups:

- 1 Union was seen in 34 patients (74 per cent), and this implies bone union of the fracture with radiographic visible trabeculation across the fracture line.
- 2 Failure was seen in 10 patients (22 per cent). This implies recurrence of the fracture deformity. This group also includes two cases of failure of the appliance. This group does not include avascular necrosis.

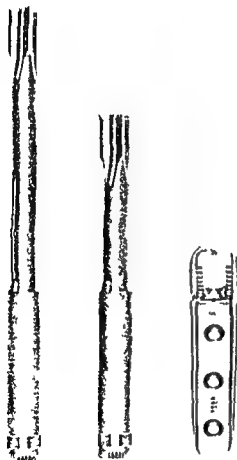


Figure 1 The sliding nail plate material. The nail component is shown in its longest and shortest position.

and definitely not above or anterior to the midpoint of the articular surface of the capital fragment. This steep position of the nail also minimizes the strain on the junction between the nail and the plate, and thus we have only seen failure of the appliance in two (3 per cent) cases where the nail slid back into the barrel followed by redisplacement of the fracture. Neiminen (1975) reported sliding outwards of the nail in 29.2 per cent and collapse of the junction between nail and side plate in 8.9 per cent in a series of patients treated with early weight bearing.

Table 5 Postoperative complications in 63 patients operated with sliding nail plate osteosynthesis for medial fracture of the femoral head

Complications	Number of patients
Death within one month	3
(cardiac diseases	5
Pulmonary diseases	7
Phlebotrombosis	0
Decubital ulcer	4
Miscellaneous	7
Deep infection	1
Total	27

If a patient had more than one complication each complication is listed separately. All together there were 21 patients with postoperative complications.

In the present study of elderly patients we aimed at a very early mobilization. As reported earlier (Brown & Abram 1964, Graham 1968, and Neiminen 1975) weight bearing 2 weeks after the operation does not deteriorate the final result. On the contrary, results indicate that early weight-bearing improves the final result compared with late weight bearing (after 12 to 14 weeks). Investigations by Skipper (1975) show that the first days after the operation the patients only put a little of their body weight on the operated leg, but within a week the ability to bear weight increases rapidly in patients with medial fractures of the femoral neck. After an average period of 53 days the patients put full weight on the operated leg.

One might expect that the early mobilization with weight-bearing would be followed by an increased incidence of non-union of the fracture and avascular necrosis of the femoral head. This has not been the case. We found that the rate of union was 94 per cent in stage 3 fractures and 61 per cent in stage 4 fractures.

As seen in Table 6, these figures do not differ from results reported earlier (Garden 1961, Brown & Abram 1964, Graham 1968, Neiminen 1975). Further, they are also in agreement with reports from Odense University Centre (Jensenius

Table 6 Survey of follow up studies after operative treatment of medial fractures of the femoral neck

	Union (per cent)		Avascular necrosis (per cent)	
	Stage 3	Stage 4	Stage 3	Stage 4
Garden 1961 (1)	93	57	29	12
Brown & Abram 1964	90	65	21	30
Graham 1968	85	71	—	26
Neiminen 1975 (2)	61	65	16	26
Present study	94	61	24	18

(1) Low angle Küntscher nail.

(2) Smith Petersen nail with or without side plate.

Table 2 Results of the follow-up related to degree of fracture displacement

Displacement	Number of patients	Union	Failed	Doubtful union	Avascular necrosis
Stage 3	18	17	—	1	4
Stage 4	28	17	10	1	3
Total	46	34	10	2	7

Table 3 Results of the follow-up related to the quality of reduction

Reduction	Number of patients	Union	Failed	Doubtful union	Avascular necrosis
Good	38	29	7	2	7
Fair	6	5	1	—	—
Poor	2	—	2	—	—
Total	46	34	10	2	7

Good Reduction is anatomical or slightly in valgus without any rotation

Fair Reduction is anatomical or slightly in valgus with some rotation

Poor Reduction is in varus or with severe rotation

Table 4 Results of the follow up related to the position of the sliding nails

Position of sliding nail	Number of patients	Union	Failed	Doubtful union	Avascular necrosis
Good	26	23	3	—	2
Fair	12	8	4	—	4
Poor	8	3	3	2	1
Total	46	34	10	2	7

Good The nail is placed in the centre or in the lower posterior quadrant of the femoral head

Fair The nail is placed in the lower anterior quadrant or in the superior posterior quadrant of the femoral head

Poor The nail is placed in the superior anterior quadrant of the femoral head penetrating the femoral head, or more than one centimetre below the cortex of the femoral head

and the fracture surfaces could no longer be brought into contact

DISCUSSION

The present sliding nail-plate osteosynthesis differs in only one major respect from other appliances (Pugh 1955, Masie 1958, Brown & Abram 1964, Ans-

worth 1971), it has no fixed nail-plate angle. The fact that the nail is connected by a topbolt to the side plate increases the possibility of obtaining an optimal position of the nail. Backman (1957) showed that the weight-bearing forces which act on the proximal end of the femur are almost vertical, and accordingly we aim at the steepest possible position of the nail resting on the calcar

QUANTITATIVE HISTOLOGIC ANALYSES OF ARTICULAR CARTILAGE AND SUBCHONDRAL BONE FROM OSTEOARTHRITIC AND NORMAL HUMAN HIPs

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Twelve femoral heads (two normal, four after fracture and six osteoarthritic) were obtained at surgery or autopsy. Circumferential slices were obtained and five separate areas were analyzed in each for ash content, histological histochemical grading of the severity of the cartilage changes and quantitative morphometric analyses to establish the percentage of trabecular area, osteoblastic area and osteoclastic area. Analyses were performed to compare weight bearing and non weight bearing areas of the femoral heads and to determine correlations between the bony and cartilaginous alterations. The data obtained showed wide variations in all parameters in the osteoarthritic specimens but consistently more marked cartilage and bony changes in the weight bearing areas. Bone structures and metabolic parameters were distinctly increased for the osteoarthritics, differing significantly from both normal and fracture control groups. The bony change correlated directly with the severity of the cartilage lesions, as determined by the histological histochemical grade.

Key words: bone mineral, cartilage degeneration, osteoarthritis, osteoblastic area, osteoclastic area, subchondral bone, trabecular bone area.

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Over the years, numerous reports have described the structural abnormalities in cartilage and subchondral bone from osteoarthritic human joints (Collins 1949, Harrison et al 1953, Sokoloff 1969, Metchum & Fergie 1975). Alterations in these tissues have been shown to be progressive with advancing disease and highly focal, particularly for the femoral

head (Mankin et al 1971), the site most extensively studied in recent years. Cartilage alterations consist of erosion, ulceration, fibrillation and progressive destruction leading to complete loss of tissue (Collins 1949, Sokoloff 1969, Metchum & Fergie 1975) while the bony changes are those of increased bone formation, thickening trabeculae, sclerosis and cyst formation (Sokoloff 1969, Radin et al 1970, Ross & Byers 1972, Jeffrey 1973). Although the concept of a relationship between the changes in the cartilaginous and bony tissues exists, it ap-

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1956, Frederiksen et al 1967). It also appears from Table 6 that the rate of avascular necrosis in our material was 24 per cent in stage 3 fractures and 18 per cent in stage 4 fractures, and even here the results do not differ.

Furthermore, it is evident from Table 6 that there is a high rate of union in stage 3 fractures and a considerably lower rate of union in stage 4 fractures. On the other hand, there is no connection between avascular necrosis and the fracture stage.

In the present study there was no clinically observed phlebothrombosis or pulmonary embolism, which, together with the low mortality (three patients within 30 days), we attribute to the early mobilization of the patients.

As stated by Spotof (1944) and Garden (1961, 1971, 1974), an exact reduction of the fracture is the basis of a high rate of union (Table 3). That an optimal internal fixation is also of importance in this respect can be seen from Table 4.

The conclusion made from this study can only be of a tentative nature due to the small number of patients, but the advantages already mentioned together with the high rate of acceptable results make it an attractive method of internal fixation of medial fractures of the femoral neck.

REFERENCES

- Ainsworth T H (1971) Immediate full weight bearing in the treatment of hip fractures. *J Trauma* 11: 1031-1040.
- Backman, S (1957) The proximal end of the femur. *Acta radiol Suppl* 146.
- Brown J T & Abram, G (1964) Transcervical femoral fracture. *J Bone Jt Surg* 46 B: 645-663.
- Frederiksen T, Greveld I, Hansen J B, Jensenius H, Langberg K & Nielsen F I (1967) The prognosis for patients with medial femoral neck fracture. *Acta chir scand* 133: 369-374.
- Garden R S (1961) Low angle fixation in fractures of the femoral neck. *J Bone Jt Surg* 43 B: 647-663.
- Garden R S (1971) Malreduction and avascular necrosis in subcapital fractures of the femur. *J Bone Jt Surg* 53-B: 183-197.
- Garden R S (1974) Reduction and fixation of subcapital fractures of the femur. *Orthop Clin N Amer* 11: 683-712.
- Graham J (1968) Early or delayed weight bearing after internal fixation of transcervical fracture of the femur. *J Bone Jt Surg* 50 B: 562-569.
- Jensenius H (1956) Osteosynthesis of medial fractures of the femoral neck. *Acta chir scand* 111: 322-332.
- Massie, W H (1958) Functional fixation of femoral neck fractures. Telescoping nail technique. *Clin Orthop* 12: 230-255.
- Nieminen S (1975) Early weightbearing after classical internal fixation of medial fractures of the femoral neck. *Acta orthop scand* 46: 782-794.
- Pugh, W I (1955) A self adjusting nail plate for fractures about the hip joint. *J Bone Jt Surg* 37 A: 1085-1093.
- Skipper A (1975) A method of measuring the ability to bear weight in patients operated for fracture of the femoral neck by applying early weightbearing. *Danish Orthop Soc* 103 Assembly. *Acta orthop scand* 46: 867-878 (abstract).
- Spotof, J (1944) Osteosynthesis collis femoris. Thesis. Copenhagen 1944.

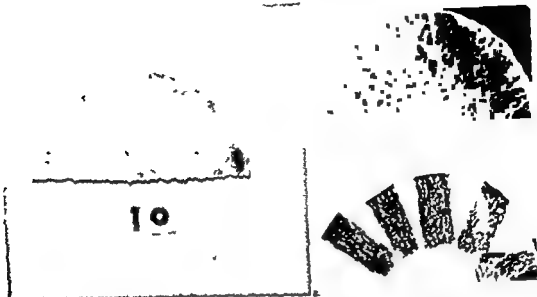


Figure 2 Slice from the normal femoral head of a male aged 61 (left) The x ray shown in the right side of the figure shows the distribution of the bone segments

evaluated by specialized morphometric techniques

The morphometric techniques utilized for this study were designed to provide a measure of total bone present (trabecular bone area per cent of total bone surface occupied by osteoblasts) anabolic activity (osteoblastic area per cent of total bone surface occupied by either osteoclasts or resorption lacunae). The trabecular bone area measurement utilized a point counting method with an integrating eyepiece of 22 points in an hexagonal lattice according to the method of Harris & Weiberg (1972). For the osteoblastic and osteoclastic area counts an integrating eyepiece with a square lattice was used according to the technique of Melton *et al.* (1953). Values were expressed as percentage of total area for trabecular bone and percentage of bone present for osteoblastic and osteoclastic areas.

RESULTS

1 Alterations in the cartilage

As can be seen from examination of Table 1 the histological histochemical grades varied considerably from site to site in the five segments studied from each femoral head, particularly in the osteoarthritic group. A total of seven of

the segments from this group had osteoarthrosis of such severity that no cartilage was present on the specimen. All of these were in the weight bearing areas.

Table 2 shows the mean values for the histological histochemical grading of cartilage from the three groups and a comparison of the values for the weight-bearing and non weight bearing areas. It should be noted that the bare areas were excluded from the calculations since the grading system provides no score for total loss of cartilage. Despite this the differences between the osteoarthritic and either normal or fracture group are significant at the $P < 0.001$ level. The fracture group also differed significantly from the normal, but with considerably less deviation. Only the osteoarthritic group showed a difference between weight bearing and non weight-bearing areas ($P < 0.01$).

2 Mineral content

The distribution of the per cent of mineral content in relation to disease and site is shown in Table 3.

pears to be based principally on biomechanical considerations (Radin et al 1973, Pugh et al 1974). To date, no attempt has been made to assess the two processes simultaneously by quantitative histological techniques.

In 1971 a report from this laboratory described a histological-histochemical grading system which provided numerical values for defining the severity of the changes in articular cartilage from osteoarthritic femoral heads (Mankin et al 1971). Progressive deterioration provided increasingly higher scores on the scale, and these data correlated well with biochemical (Mankin et al 1971) and enzyme (Ehrlich et al 1973) abnormalities in the cartilage. The system does not measure changes in the subchondral bone, and no such grading system for the bone is available.

This report describes an experiment which sought to develop morphometric techniques to assess the alterations in subchondral bone and then apply both these and the previously described cartilage grading system to a series of control and osteoarthritic femoral heads. Furthermore, it also assesses the variation in the morphometric parameters from site to site and also compares these for osteoarthritic tissue as well as for the normal groups.

MATERIAL AND METHODS

Twelve femoral heads were used for this study and divided into three groups. A normal group consisting of two femoral heads obtained at autopsy from two male patients aged 60 and 61. A fracture group consisting of four femoral heads obtained at the time of replacement surgery, which took place immediately after the fracture from female patients with an average age of 79.5 and an osteoarthritic group consisting of six femoral heads obtained at the time of replacement surgery from four female and two male patients with an average age of 57.8. Specimens were fixed for 24 hours in 10 per cent buffered formalin phosphate and then two circumferential slices were cut at



Figure 1 Demonstration of the use of the hand saw to cut parallel circumferential sections of the femoral heads

exactly 15 mm in thickness using a Bronwill TSM 77 hand saw (Figure 1). The sections were taken in such a way as to include both weight bearing and non weight bearing areas. At the time they were obtained they were photographed and microradiographs were made using a Machlett apparatus (exposure time one hour at 20 kV and 20 mA). Five equally sized rectangular slices were obtained from each section in a manner so as to include both weight bearing and non weight bearing areas (Figure 2).

The five sections from one of the two circumferential slices were used to determine mineral content. The samples were fixed in 80 per cent ethanol with three changes over a period of 48 hours. After freeze drying at -50°C for three hours the bone pieces were weighed and then ashed at 600°C for 18 hours and reweighed using a microbalance.

The second group of five sections was fixed in 10 per cent buffered formalin phosphate then decalcified, dehydrated and embedded in paraffin. Samples were cut at six micra and stained with hematoxylin and eosin and Safranin O iron hematoxylin fast green for histologic study (Mankin et al 1971). The degree of cartilage degeneration and destruction was evaluated for each of the five segments from the Safranin O stained preparations according to the histological histochemical grading system of Mankin et al (1971). Four microscopic areas of the subchondral bone from each of the five samples were randomly selected for study. Two of these were considered to be at the surface and the other two lay one lattice depth subjacent to that region (deep). In all a total of 240 areas were

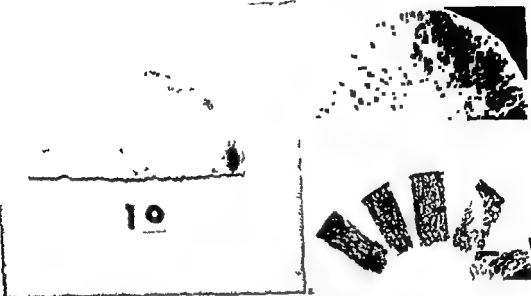


Figure 2 Slice from the normal femoral head of a male aged 61 (left) The x ray shown in the right is of the slice of the femoral head showing the distribution of the bone segments

evaluated by specialized morphometric techniques

The morphometric techniques utilized for this study were designed to provide a measure of total bone present (trabecular bone area per cent of total bone surface occupied by osteoblasts) and catabolic activity (osteoblastic area per cent of total bone surface occupied by either osteoclasts or resorption lacunae). The trabecular bone area measurement utilized a point-counting method with an integrating eyepiece of 100 points in an hexagonal lattice according to the method of Harris & Weinberg (1977). For the osteoblastic

area measurement the area was expressed as percentage of total area for trabecular bone and percentage of bone present for osteoblastic and osteoclastic areas

RESULTS

1 Alterations in the cartilage

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2 Mineral content

The distribution of the per cent of mineral content in relation to disease and site is shown in Table 3.

Table 1 Distribution of the histological histochemical grades in the cartilage with relation to age, sex, diagnosis and area

Specimen No	Age	Sex	Diagnosis	Histological histochemical grade	
				WB	Non WB
2	66	I	Osteoarthritis	- -	3 8
4	65	I	Osteoarthritis	13 8 8	5 4
5	46	M	Osteoarthritis	5 5 7	4 2
7	59	F	Osteoarthritis	- - 12	1 2
9	59	I	Osteoarthritis	12 12 -	13
11	52	M	Osteoarthritis	6 13 13	2 13
3	73	F	Fracture	0 2	3 2 7
6	78	I	Fracture	1 4 1	1 2
8	82	I	Fracture	2 3 2 4	5
12	85	I	Fracture	2 2 2	2 2
10	61	M	Normal	0 2 2	0 1
13	60	M	Normal	0 1 2	0 1

- No cartilage remaining

Table 2 Variation of histological histochemical grade with diagnosis and site

	All sites	Weight bearing	Non weight bearing
Normal (10)	0.90 ± 0.88	1.17 ± 0.98 (6)	0.50 ± 0.58 (4)
Fracture (20)	2.45 ± 1.57	2.08 ± 1.16 (12)	3.00 ± 2.0 (8)
OA (23)	7.30 ± 4.51*	9.50 ± 3.9 (12)	5.18 ± 4.31 (11)
	$P < 0.001$ $P < 0.001$	$P < 0.01$	

* Excludes 7 of 16 sites on the weight bearing areas of the osteoarthritic femoral heads which were bare of cartilage

* Standard deviation

* As determined by Student's *t* test

As can be noted the osteoarthritic samples showed a significant ($P < 0.001$) increase in ash content compared with either normal or fracture groups. Differences between weight bearing and non weight bearing areas for the normal and fracture groups were just barely significant ($P < 0.02$ and $P < 0.10$ respectively) but for the osteoarthritic sub

chondral bone it was highly significant ($P < 0.005$). The difference between the ash content of the non weight bearing areas was moderate (a 17 per cent increase in the osteoarthritic group over the other two at the 10 per cent confidence level) but marked in the weight bearing areas (~27 per cent increase for the osteoarthritic group with $P < 0.005$).

Table 3 Variation of percentage mineral content with disease and site studied

	All sites	Weight bearing area	Non weight-bearing area
Normal (10)	30.42 \pm 4.03*	32.72 \pm 2.64 (6)	26.99 \pm 3.27 (4)
		$P < 0.02$	
Fracture (20)	29.39 \pm 4.64 n.s.*	31.16 \pm 4.15 (12) n.s.	26.99 \pm 4.71 (8) n.s.
		$P < 0.10$	
OA (30)	33.78 \pm 7.54 $P < 0.001^*$ $P < 0.001^\dagger$	40.60 \pm 10.01 (19) $P < 0.005$ $P < 0.001$	31.82 \pm 5.71 (11) $P < 0.10$ $P < 0.10$

* Standard deviation

* Significance of variation from the control group as determined by Student's *t* test.

† Significance of variation from the fracture group

Table 4 Comparison of morphometric parameters for surface and deep zones

	Per cent trabecular bone area	Per cent osteoblastic area	Per cent osteoclastic area
Normal (10)			
Surface	30.45 \pm 2.22†	24.32 \pm 2.53	1.45 \pm 0.83
Deep	19.63 \pm 3.60	20.28 \pm 4.60	1.59 \pm 0.63
Fracture (20)			
Surface	16.14 \pm 4.61*	22.53 \pm 12.10	3.34 \pm 1.21*
Deep	16.02 \pm 3.51*	20.29 \pm 12.52	3.23 \pm 1.39*
OA (30)			
Surface	32.55 \pm 10.97**	44.20 \pm 13.84**	4.21 \pm 2.06*
Deep	26.29 \pm 8.20**	31.60 \pm 8.95**	3.64 \pm 1.73*

† Standard deviation

* Indicates significant difference between deep and superficial zones (as determined by a

3 Bone morphometric analyses

In Table 4 all three morphometric parameters for both superficial and deep zones are compared. Table 5 shows a comparison of the weight-bearing and non-weight-bearing areas for the same measurements.

(a) Per cent of trabecular bone area

A significant decrease was noted in the

per cent of trabecular bone area in the fracture population compared with the controls, presumably reflecting the fairly marked difference in average age of the two groups and sex variation (see below). This is perhaps an indication of the sensitivity of the method since it is possible to detect the small difference in bone density associated with aging.

Table 5 Variation in morphometric parameters for surface and deep zones in weight bearing and non weight bearing areas

	Per cent trabecular bone area		Per cent osteoblastic area		Per cent osteoclastic area	
	WB	NWB	WB	NWB	WB	NWB
Normal		(4)	(6)	(4)	(6)	(4)
Surface	20.83 ± 2.24†	19.88 ± 2.18	25.81 ± 1.80	22.09 ± 3.62	1.57 ± 0.78	1.28 ± 0.90
Deep	21.59 ± 1.91	16.82 ± 6.14	22.22 ± 3.16	17.37 ± 7.25	1.51 ± 0.45	1.27 ± 0.88
Fracture	(12)	(8)	(12)	(8)	(12)	(9)
Surface	18.75 ± 5.41	12.22 ± 3.42*	20.85 ± 11.72	25.04 ± 12.84	3.02 ± 1.11	3.81 ± 1.37
Deep	18.18 ± 3.88	12.78 ± 2.96*	19.04 ± 11.75	22.16 ± 13.67	3.17 ± 1.39	3.34 ± 1.39
OA	(19)	(11)	(19)	(11)	(19)	(11)
Surface	36.97 ± 11.73	25.00 ± 9.75*	48.44 ± 15.05	36.67 ± 11.72*	5.03 ± 2.32	2.80 ± 1.61*
Deep	29.55 ± 8.78	20.66 ± 7.22*	31.85 ± 8.72	31.16 ± 9.43	3.84 ± 2.13	3.20 ± 1.03

† Standard deviation

* Significant difference between weight bearing and non weight bearing zones as determined by Student's t test with $P < 0.01$

Of greater significance to this study, however, was the rather marked increase (~ 60 per cent) in the percentage of trabecular bone in the osteoarthritic surface zone and the slightly less marked increment for the deeper zone (Table 4). Compared with the fracture group, the osteoarthritides were markedly hyperostotic with an increase of over 100 per cent for the trabecular bone area in the surface zone.

Analyses of the differences between trabecular bone areas for the weight-bearing and non-weight bearing areas showed no difference for the normal group but there was a significant increase in the weight bearing area for both the fracture group and the osteoarthritides (~ 50 per cent) (Table 5). In both cases the variation was slightly less marked in the deeper zones.

(b) *Per cent of osteoblastic area* The percentage of bony surface involved in osteoblastic activity ranged between 18 per cent and 25 per cent for both normal and fracture groups and appeared to vary little with either the surface or deep

zones or the weight bearing and non weight bearing areas (Tables 4 and 5). In contrast, the osteoarthritic subchondral bone showed a marked increase in osteoblastic activity with over 40 per cent of the bony surface engaged in new bone formation. This represents a significant variation in relation to both control groups with an almost 100 per cent increase for the surface zone and over 55 per cent for the deep zone (Table 4). The surface zone showed approximately 40 per cent greater activity than the deep zone (Table 4) and the value for the weight bearing area exceeded that for the non-weight-bearing by over 30 per cent (Table 5).

(c) *Per cent of osteoclastic area* The percentage of bony surface involved in osteoclastic activity was very low in all groups and at all sites, ranging from 1.27 per cent to 5.03 per cent. The values were least in the normal, greater in the fracture and highest in the osteoarthritic group (Table 4). No significant difference was noted between the surface and deep zones for any of the groups and

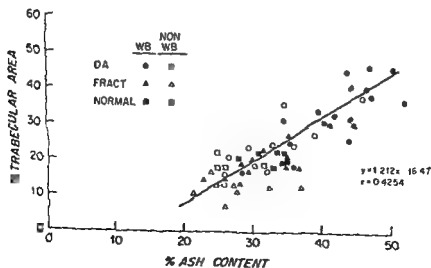


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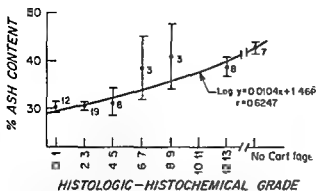


Figure 4 Graphic representation illustrating the relationship between the histological histochemical grade of the articular cartilage and the per cent of mineral content for the osteoarthritic fracture and normal femoral heads

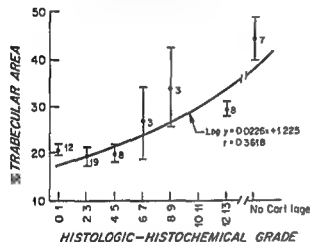


Figure 5 Diagram illustrating the relationship between the histological histochemical grade and the per cent of trabecular area

only the osteoarthritides showed a difference between weight-bearing and non-weight-bearing areas (Table 5)

4 Correlations

As an "internal control" for the methods, the percentage mineral content was compared with the trabecular bone area. As can be noted in Figure 3, the relationship is linear and has a coefficient of correlation of 0.4254. Since only the per cent of trabecular area for the surface zone was included in the calculations (while the per cent of mineral content determination included both the surface and deep zones), this observation serves

only as a crude corroboration of the methods.

Of greater importance and central to the theme of the study were the correlative data regarding the histological histochemical grading and the per cent of ash and bone morphometric analyses. Figures 4, 5, 6 and 7 show the correlative data in two forms: groupings with deviations for each data point and correlations as determined by regression analysis. Only the surface morphometric studies were included. As can be seen, the correlations for all but the per cent of trabecular area were of moderate significance. Most

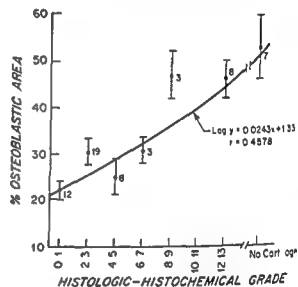


Figure 6 Diagram showing the relationship between the histological histochemical grade and the per cent of osteoblastic area for all specimens

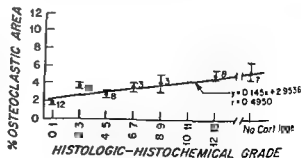


Figure 7 Graphic representation illustrating the relationship between the histological histochemical grade and the per cent of osteoclastic area for all specimens

closely correlated was the percentage ash content ($r = 0.6247$) while per cent of osteoblastic and osteoclastic areas were of slightly lesser significance ($r = 0.4950$ and 0.4578 , respectively). The correlations were all non linear except for the per cent of osteoclastic activity.

DISCUSSION

Before discussing the significance of the data obtained in this study, it is important to review the methods and some possible sources of error. First, in regard to methods, the histological histochemical grading system has been shown to correlate well with biochemical abnormalities in osteoarthritic articular cartilage (Mankin et al 1971) and with increase in enzyme levels in the tissue (Ehrlich et al 1973). Its principal value is in providing a technique to evaluate a small focus and hence avoid the problems of the highly focal nature of the osteoarthritic process (Sokoloff 1969). Other methods of classification, especially that of Collins (1949), utilize a more macroscopic approach and are of little value in a study such as this.

One problem of the grading system is that no score is possible when the cartilage is totally absent. For purposes of determination of the correlation curves in Figures 4, 5, 6 and 7, an arbitrary value of 16 was awarded to those segments in which no cartilage was found. The shape of the curves (and indeed the coefficient of correlation) might have been different if another value (such as 20 or 25) had been used.

The bone morphometric techniques used in this study are fairly standard and providing they are randomized are considered to be reasonably valid (Harris & Weinberg 1972; Melsen et al 1975). The problem of application to osteoarthritic subchondral bone lies principally in relation to cysts and areas of

microfracture. Since random-site selection was strictly adhered to and thus no attempt made to preselect non-cystic or non-callus areas, this could in theory have introduced a source of error. It should be noted, however, that only the per cent of trabecular area

$$\frac{\text{trabecular bone}}{\text{total area}} \times 100,$$

could be affected by the presence of cysts or fracture callus since the other determinations are based on total bone present. This may explain the slightly poorer correlation of the per cent of trabecular bone area observed with the histological-histochemical grade (Figure 5).

As previously noted by Harrison et al (1953), variable amounts of osteonecrosis (as determined by empty lacunae) were noted in the subchondral bone of the osteoarthritic specimens, particularly in the weight bearing area. Although a presumably important factor in the pathogenesis of the bony changes, the finding did not alter the morphometric observations and was not quantified in this study.

Two "internal controls" were utilized. The first was the inverse correlation of the per cent of trabecular bone area with patient age and sex in the two control groups. The two normal femoral heads were from males aged 60 and 61 years, those in the fracture group were all from females with an average age of 79.5. On the basis of both sex and age, the fracture group should have been considerably more osteopenic than the controls, and this is clearly evident in the data shown in Table 4. As a second internal control, the per cent of ash weight was correlated with the per cent of trabecular bone and showed a linear correlation of moderate significance (Figure 4).

One additional problem in the study is related to selection of specimens. Although the diagnosis was controlled in the sense that the two normal femoral

heads were indeed normal and the osteoarthritics showed extensive changes of disease, the fracture group showed several sites on the femoral heads which displayed mild to moderately severe osteoarthritis. Of perhaps greater importance was the fact that sex and age, both of which have a significant effect on bone mass, were not controlled. The ages for the three groups differed somewhat (especially the fracture group) and the normal specimens were both from males, in the fracture group all from females, and in the osteoarthritic group from four males and two females. For these reasons, the authors utilized the younger, male control specimens upon which to base variations observed in the osteoarthritic group, particularly where a difference was noted between the normal and fracture groups.

In consideration of the experimental results, several points are clearly evident. First, the histological-histochemical grading of the osteoarthritic cartilage showed wide variation from site to site and more severe changes in the weight-bearing areas. These data confirm prior observations from this laboratory (Mankin et al 1971).

Second, the per cent of mineral content and all bone morphometric parameters showed highly significant increments in the osteoarthritic subchondral bone compared with either the control or fracture group. Thus, not only is there evidence for a hyperostosis in the subchondral area, but also a fairly profound increase in metabolism reflected by increased rates of both osteoblastic and osteoclastic activity.

Of perhaps greater interest was the relationship of these changes to site on the femoral head. In all morphometric measurements, the osteoarthritic weight-bearing area showed greater increases than the non-weight-bearing area with increments above the control values of 27 per cent for ash control 50 per cent

for the per cent of trabecular area, 30 per cent for the per cent of osteoblastic area and even greater increments for the per cent of osteoclastic area. Furthermore, when looking at the zone extending no more than 5 mm deep to the subchondral surface ("deep" zone), these variations were for the most part significantly reduced. These variations with site are consistent with those reported by Foss & Byers (1972), Radin et al (1970, 1973), and Pugh et al (1974), but differ from the observations of Lereim et al (1975) who found no significant difference in the density of subchondral bone from the weight-bearing area of osteoarthritic joints and that from the non-weight-bearing area or from normal controls.

The principal purpose of this study was to assess if the cartilage changes (which are believed to be an indicator of the severity of the osteoarthritic process) could be correlated with the bony abnormalities as determined by the per cent of mineral content and the morphometric analyses. The correlation curves shown in Figures 4, 5, 6 and 7 indicate a direct relationship between the two groups of parameters of moderately high significance ($r = 0.500$) with the exception of the bone trabecular area which correlated less well ($r = 0.4254$). These data define an association between the two biologic processes: degeneration of the cartilage and sclerosis and hypermetabolism of the subchondral bone.

There are insufficient data from this experiment to indicate whether the two processes, one bony and the other cartilaginous, are related to one another in an etiologic way, as has been suggested by Pugh et al (1971) and Radin et al (1970) or whether the two are responding separately (and oppositely) to some other mechanical or chemical stimulus. Although it is possible that the findings are the result of a multiplicity of independent factors, the close inverse

concordance allows speculation that the two processes are interdependent and possibly represent two divergent responses to a single biologic alteration

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REFERENCES

- Collins D H (1949) *The pathology of articular and spinal diseases* pp 74-115 Edward Arnold & Co London
- Ehrlich M G, Mankin H J & Treadwell B V (1973) Acid hydrolase activity in osteoarthritic and normal human cartilage *J Bone Jt Surg* 55-A 1068-1076
- Foss M V L & Byers P D (1972) Bone density osteoarthritis of the hip and fracture of the upper end of the femur *Ann Rheum Dis* 31 259-264
- Jeffrey A H (1973) Osteogenesis in the osteoarthritic femoral head *J Bone Jt Surg* 55 B 262-272
- Harris W H & Weinberg F H (1972) Microscopic method of measuring increases in cortical bone volume and mass *Calcif Tissue Res* 8 191-196
- Harrison M H M, Schajowicz F & Trneta J (1953) Osteoarthritis of the hip. A study of the nature and evolution of the disease *J Bone Jt Surg* 35 B 508-626
- Lerem P, Langeland N, Romanus H, Pettersen J F & Goldie I F (1975) A biochemical analysis of subchondral bone of the medial tibial condyle in normal state and in osteoarthritis *Acta orthop scand* 46 672-684
- Mankin H J, Dorfman H, Lippicello L & Zarins A (1971) Biochemical and metabolic abnormalities in articular cartilage from osteoarthritic human hips *J Bone Jt Surg* 53 A 523-537
- Meachim G & Fergie I A (1975) Morphological patterns of articular cartilage fibrillation *J Path* 115 231-240
- Nelsen F, Moschilde L & Beck-Nielsen H (1975) kvantitativ histologisk undersøgelse ved metaboliske knogelidelser *Lægek Læg* 137 933-936
- Pugh J W, Radin E L & Rose R M (1974) Quantitative studies of human subchondral cancellous bone. Its relationship to the state of its overlying cartilage *J Bone Jt Surg* 56 A 313-321
- Radin E L, Parker G H & Pugh J W (1973) Response of joints to impact loading III. Relationships between trabecular microfracture and cartilage degeneration *J Biomech* 6 51-57
- Radin F L, Paul I L & Tolhoff M J (1970) Subchondral bone changes in patients with early degenerative joint disease *Arth Rheum* 13 400-405
- Sokoloff L (1969) *The biology of degenerative joint disease* The University of Chicago Press Chicago

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EARLY AND LATE RESULTS OF BRACKETT'S OPERATION FOR PSEUDARTHROSIS OF THE NECK OF THE FEMUR IN INFANTILE COXA VARA

A Review of 30 Operations

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The early and late results of 30 Brackett operations for pseudarthrosis of the neck of the femur are reviewed. The cause of the pseudarthrosis in 28 hips was congenital or infantile coxa vara. The patients' ages at the time of the operation ranged from 2 to 43 years. The early results were good. Only three out of a total of 30 cases failed to unite, 27 hips became stable. Necrosis of the femoral head occurred in six hips. Late results, on average 13 years after the operation, differed greatly from the early results. The majority of the hips were stable but only three completely painless. All but four were affected by secondary osteoarthritis which in six cases was slight.

Key words Brackett's operation, pseudarthrosis of the neck of the femur, infantile coxa vara

Accepted 25 x 76

Brackett & New published their primary results in 1917. The results of the Brackett operation have been reviewed by Brackett (1938), Magnuson (1932, 1940), Rowe & Ghormley (1944), Ivins & Ghormley (1947), and Merle d'Aubigne & Thomine (1968), who treated pseudarthroses following a fracture, whereas Babb et al (1949), Långenskiöld (1949) and Pylkkänen (1960) reviewed the results after treatment for pseudarthrosis of the femoral neck in congenital or infantile coxa vara.

The purpose of the present study is to ascertain the early and late results of the Brackett operation in non-union of the femoral neck caused by congenital or infantile coxa vara, and also in two chil-

dren with non-union of the femoral neck from other causes. The purpose was also to find out whether this operation may still be indicated in certain cases.

PATIENTS AND METHODS

From 1945 to 1968 Brackett's operation was carried out at the Orthopaedic Hospital of the Invalid Foundation on 29 patients (14 male and 15 female). Both hips were operated on in one patient, and the total number of hips treated was thus 30. The cause of the pseudarthrosis was coxa vara infantum in 28 hips. A two-year-old child with congenital dislocation of the hip and an eight-year-old child with a pseudarthrosis of traumatic origin were also included in the series. The patients' ages ranged from 2 to 43 years. At the time of the operation 12 of the patients were children. A follow-up exam-

Table 1 Age of patients at operation and at follow-up and duration of follow-up

		Age at operation						
Years		2-9	10-14	15-17	18-19	20-24	25-29	30-34
No of hips		3	2	7	3	8	3	4
		Age at follow-up						
Years		16-19	20-24	25-29	30-34	35-39	40-44	45-61
No of hips		3	3	3	7	5	4	5
		Duration of follow up						
Years		1-4	5-9	10-14	15-19	20-24	25-29	
No of hips		5	4	6	9	3	3	

mation was carried out in the spring of 1972 on a total of 20 hips which were examined both clinically and roentgenologically. Running follow up entries with radiographs were available in the hospital records of all of the patients as well as of the 10 patients who failed to attend this particular follow up examination. The follow up periods ranged from 1 to 29 years, average 13 years. At the time of the follow-up examination or at the last visit to the outpatient clinic, nearly all patients were fully grown (Table 1).

Operative technique

An antero-lateral incision was made in the interval between the tensor fasciae latae and the rectus femoris muscles. The joint capsule was incised in line with the femoral neck to reach the pseudarthrosis. All dense scar tissue of the non union was excised. In the first four operations the freshened cancellous bone surface was placed end to end without excavation of the femoral head. The results were not good and therefore in all the other hips the femoral head was excavated to form a concavity or a socket for the distal fragment. Next the remnant of the neck was removed and an osteotomy of the proximal part of the greater trochanter with its attached muscles was performed. The shaft was inserted as deep into the head of the femur as was possible without breaking the articular surface of the head. The word implantation has therefore been used to describe the procedure. The greater trochanter was fixed either by a screw or a wire to the upper lateral surface of the femur. If necessary the tension of the adductor muscles was relieved by tenotomy performed through a separate incision. No metal or bone fixation between the head and shaft of the femur was used.

The extremity was immobilized in plaster for 6 to 8 weeks. Active mobilization of the limb was commenced thereafter and depending on the

degree of consolidation verified roentgenologically, the patient was allowed to start walking one or two months after the removal of the plaster.

RESULTS

The series is heterogeneous as regards the patients' ages. The age at operation varied between 2 and 43 years, and at follow-up between 16 and 61 years. The early results are those which became manifest during the first postoperative year, while those observed after the first year are classified as late results.

Early results

No fatal complication occurred. On three occasions there was a superficial wound infection. Deep thrombosis developed in three instances. The consolidation was successful in all three cases.

During the operation, the proximal end of the femoral shaft could be placed in a good, central position inside the head on 16 occasions compared with the upper part of the head on 10 occasions. On four occasions the operation was made without excavating the head.

Necrosis of the head was seen one year postoperatively in six hips. In three the operation had been made without excavating the femoral head, in two the shaft was in contact with only the upper part of the head, and in one the head, which originally had been well fitted, postoperatively slipped into a bad posi-

Figure 1 a A 17 year old boy Pseudarthrosis of the femoral neck has developed from infantile coxa vara of the right hip. The head of the femur is completely detached from the neck but despite considerable decalcification its articular cartilage is smooth and its shape is normal. Clinical investigation showed that Trendelenburg's sign was decidedly positive, the patient had a bad limp and mobility of the hip was greatly restricted. Owing to pain in the hip the patient was only able to do light work.



Figure 1 b Braillet's operation was performed 18 months later. The radiograph was taken 6 weeks postoperatively. The femoral shaft is well implanted and fitted into the head of the femur.



Figure 1 c Radiograph taken 18 years after Braillet's operation. The patient is now 36 years old, is a labourer. The hip is tender on exertion and has become stiffer, but Trendelenburg's sign is negative. The femoral head is still the same in shape and incipient slight osteoarthritis is visible.





Figure 1: Axial radiograph taken 18 years after operation in this direction the shape of the head is very good

tion. In only one case of necrosis of the head did the osteosynthesis fail to consolidate.

Initially the overall mobility of the hips diminished in 19 and remained unchanged in 11 cases. Ten of those who retained mobility shared the following features: a good implantation was reached at the operation; it still remained good postoperatively; and union was soon established. Preoperatively nine patients had an extension deficit of a minimum of 30° and a maximum of 60°. These deficits were eliminated by the Brackett operation.

Length differences between the two legs ranged preoperatively from 2 to 7 cm. In only four patients were the legs of equal length. The operation increased the difference in lengths in 10 patients by 1 to 3 cm and reduced it in 10 by 1 to 3 cm; in the others the difference remained unchanged.

Preoperatively, Trendelenburg's sign was positive in all pseudarthrotic hips. Postoperatively it was negative in all those in which the osteotomy had consolidated, and positive only in three hips that did not unite (Table 2).

Table 2: Early and late results after Brackett's operation

	Early results	Late results ¹⁾
Trendelenburg's sign		
markedly positive	3	3
slightly positive		0
negative	27	16
Pain		
at rest		14
in walking	0	8
none	31	3
Arthrosis		
marked	-	15
slight		6 ²⁾
none	30	4 ²⁾

¹⁾ Five patients were followed up from 1961 to 1964 and 20 in 1972, whereas five patients were not seen after 1957 and the late results of these are not known.

²⁾ All patients without osteoarthritis and half of the patients with slight osteoarthritis were under twenty-one years of age at the time of the operation.

Late results

The majority of the patients of these series treated with the Brackett operation had been followed up in 1957 (Pykkanen 1960). Five patients were subsequently re-examined from 1961 to 1964 and 19 patients with 20 treated hips in 1972. Only four patients had no osteoarthritis and one had an ankylosed hip. All patients with osteoarthritic hips suffered from pain on exertion and two thirds of these had pain even at rest. Yet Trendelenburg's sign was markedly positive in only three non-union hips, slightly positive in six hips and the rest of the hips were stable.

As a result of secondary osteoarthritis

Figure 1 a A 17 year old boy. Pseudarthrosis of the femoral neck has developed from infantile coxa vara of the right hip. The head of the femur is completely detached from the neck, but despite considerable decalcification its articular cartilage is smooth and its shape is normal. Clinical investigation showed that Trendelenburg's sign was decidedly positive, the patient had a bad limp and mobility of the hip was greatly restricted. Owing to pain in the hip the patient was only able to do light work.



Figure 1 b Bracht's operation was performed 18 months later. The radiograph was taken 6 weeks postoperatively. The femoral shaft is well implanted and fitted into the head of the femur.



Figure 1 c Radiograph taken 18 years after Bracht's operation. The patient, now 35 years old, is a labourer. The hip is tender on exertion and has become stiffer, but Trendelenburg's sign is negative. The femoral head is flattened in shape and incipient slight osteoarthritis is visible.



the time the secondary osteoarthritis sets in the patients are older, and it should be anatomically possible to perform a total prosthesis operation on their hips. Such an operation has been successfully carried out once, 29 years after the Brackett operation.

It is self evident that severe coxa vara cases must be treated by extra articular osteotomy before the development of a pseudarthrosis. Union of a pseudarthrosis can be considered impossible to achieve (Johanning 1952). The reconstruction of the femoral neck, once it has disappeared by means of trochanteric osteotomies and bone grafts (e.g., those described by Pauwels (1949) and Müller (1971)) is extremely difficult. In certain hips, primarily those of children and young adults with long standing pseudarthroses, a good result can be achieved with the Brackett operation.

REFERENCES

- Dobb M S, Chormley R H & Chatterton C C (1949) Congenital coxa vara. *J Bone Jt Surg* 31 A 113-131.
 Brackett F G (1938) Reconstruction operations for old ununited fractures of the neck of the femur. *J Bone Jt Surg* 20 93-96.

- Brackett F G & New M S (1917) Treatment of old ununited fracture of the neck of the femur by transplantation of the head of the femur to the trochanter. *Boston med surg J* 177 351-353.
 Evans J C & Ghormley R H (1947) Brackett operation for ununited fracture of the neck of the femur. *Surgery* 14 819-825.
 Johanning K. (1932) Coxa vara infantum. Treatment and results of treatment. *Acta orthop scand* 22 100-120.
 Laugenskjöld F (1949) On pseudarthrosis of the femoral neck in congenital coxa vara. *Acta chir scand* 88 568-575.
 Magnuson P H (1932) The repair of ununited fracture of the neck of the femur. *J Amer med Ass* 98 1971-1974.
 Magnuson P B (1940) Report of fifty nine consecutive cases of ununited fracture of the neck of the femur. *Surgery* 7 763-772.
 Merle d'Aubigne R & Thomine J M (1968) La pénétration cervico capitale dans le traitement des pseudarthroses du col fémoral. *Rev Chir orthop* 54 321-333.
 Müller M E (1971) *Die hüftnahen Femur osteotomien*. Georg Thieme Verlag Stuttgart.
 Pauwels F (1949) Grundsätzliches über Indikation und Technik der Umlagerung bei Schenkelhalspseudarthrosen. *Langenbecks Arch Klin Chir* 262 404-422.
 Pääkkänen P (1960) Coxa vara infantum. *Acta orthop scand* Suppl 48.
 Rone L & Ghormley R K (1944) Brackett operation for ununited fracture of the neck of the femur. *J Bone Jt Surg* 26 249-256.

the mobility of every second hip had diminished since the 1957 follow-up examination. The hips without osteoarthritis had retained their mobility, and were even more mobile than before the operation.

A feature common to all hips without osteoarthritis was that the proximal end of the femoral shaft had initially been brought into a good, central position inside the femoral head and the consolidation was rapid. The average follow-up period was 18 years. Three of the patients were engaged in heavy manual work, and one went to a high school. At the time of the operation their ages had been 2, 19, 20 and 20 years, respectively.

In five of the hips with slight osteoarthritis a good implantation was achieved, and in only one was the contact of fragments poor. The initial consolidation was good. The average follow-up period for this group was 17 years. At the time of the operation three had been over 20 years, and the others younger.

Whatever may have been left of the epiphyseal plate, it is removed in Brackett's operation, and the neck of the femur, therefore, cannot be expected to grow postoperatively. The epiphysis of the greater trochanter is not destroyed by the operation, and growth could be observed in children. On one occasion a trochanteric epiphysiodesis had to be performed. In three children, longitudinal growth of the healthy lower limb was restricted by means of a distal epiphysiodesis of the thigh and/or a proximal one of the leg. On one occasion, a shortening operation was performed. In children, the growth of the femoral head is of the greatest interest. In the operation, a cartilaginous femoral head comprising only a little cancellous bone is implanted on the top of the shaft. Despite this the head can grow moderately and retain a relatively good, almost spherical shape (Figure 1 a, b, c, d).

DISCUSSION

The purpose of this operation must be to obtain a painless, stable and mobile hip without shortening the limb. Is the attainment of such a good result possible?

The procedure is a radical intra-articular operation. It is carried out to repair long-standing pseudarthroses. The method treats the femoral head as if it were a real sequestrum (Brackett & New). The purpose is to create an extensive and firm contact between the freshened cancellous bone surface of the femoral head and the proximal top of the shaft, so that vascularization should soon invade the femoral head from the shaft and union take place rapidly.

Owing to the pseudarthrosis, the cartilaginous surface of the femoral head and the articular socket are probably affected with degenerative changes, and the atrophied head is osteoporotic. Apparently, the shape of the head no longer fully corresponds to that of the socket. This can perhaps remodel itself postoperatively in children but not in adults.

Anatomically, the reconstruction remains deficient. Because of absence of the femoral neck and the displacement due to the pseudarthrosis it would not have been possible to preserve the neck by the technique described by Merle d'Aubigne & Thomine (1968).

It is easy to understand that such a hip cannot withstand decades of strain. A premature osteoarthritis can be expected. It is also evident that the postoperative mobility of the hip is restricted. Even the movement of the pseudarthrosis is "lost". However, the hip becomes painless and stable, and the limb is not shortened.

Prosthetic replacement cannot be recommended for children and young adults of working age. The Brackett operation helps the patient to get along for some twenty years, and in some cases a permanently good result is obtained. By

days before and 3 months after the operation. Pressure measurements were performed according to Arnoldi et al (1971).

All patients included in this series had a preoperative femoral head pressure over 40 mmHg and/or a femoral neck pressure over 30 mmHg. The preoperative mean pressure in the femoral head was 59.9 mmHg (range 48.8-85.1) and the mean pressure of the femoral neck was 44.3 mmHg (range 16.2-79.0) (Table 1). At the follow up investigation 3 months after operation 2 patients had obtained complete relief of rest pain and the other 8 reported partial relief of rest pain (Table 1). The postoperative pressure recordings in the femoral head and neck showed a mean reduction of 9.7 mmHg for both measurement sites. This difference is significant at the 5 per cent level (Wilcoxon's signed rank test). The mean reduction was 8.9 mmHg in the femoral head and 10.4 mmHg in the neck. These reductions for each site alone are not statistically significant at the 5 per cent level.

Radiographic method

Intraosseous phlebography was performed through one of the needles previously introduced for pressure measurements in the femoral head and neck. Two ml of the contrast medium Iopaque (cerebral) (Nyegaard & Co) was injected manually at an even rate. In the preoperative investigations the injection time in 4 patients was 30 seconds. In the other 4 patients the injection evoked a reaction of moderate or intense pain and the injection time had to be extended to a maximum of 70 seconds. In the postoperative investigations one injection was performed in 45 seconds because of pain and the other 7 were performed within 30 seconds each. A tube (Bj 150/30/50 R Siemens) with a focus of 0.6 mm \times 0.6 mm was used. The focus-film distance was 90 cm. An AOT film changer (Flema Schönder) with high speed intensifying screens was used. The films (Rapid H 100 F-W Ilford) were exposed with the patient in the supine position using 70 to 75 kilovolts and 400 milliamperes with an exposure time of 0.16 seconds. Only anterior-posterior series were done.

The first film was taken immediately after injection of the contrast medium and further films were exposed every 5th second during the first minute, every 15th second during the 2nd and 3rd minute, then every 2nd minute for 12 minutes and finally every 5th minute for 15 minutes. Thus the exposure program ran for 30 minutes. All phlebographic examinations were done immediately after previous pressure recordings. In the postoperative investigation an attempt was made to position needles as closely

as possible to the same points as prior to operation.

The phlebograms were assessed with regard to the drainage pattern and drainage time of the injected contrast medium. The drainage pattern shows the distribution of contrast outflow between intramedullary sinusoids (Figure 1) and extraosseous veins (Figure 2) from the neck or head of the femur. The extent of drainage through these channels was recorded. The outflow through different extraosseous veins was not studied in detail.

The drainage time was taken as the number of minutes elapsing between the injection of contrast medium and the first film obtained completely free of visible contrast medium. Pooling of contrast medium around the tip of the needle was ignored. The drainage time was recorded separately for the intraosseous vessels and extraosseous veins.

RESULTS

Before the operation, 7 patients showed pathological phlebograms with a more or less distinct intramedullary drainage pattern (Figure 1). The postoperative drainage patterns were mainly unchanged compared with the preoperative ones in 5 patients (Table 1). Two patients (Nos 3 and 4) showed a more pronounced intraosseous drainage pattern after the operation and one became more extraosseous (No 2).

The preoperative drainage time from the intraosseous space was over 6 min in 6 patients (Table 1). In 5 patients an increase in intraosseous drainage time was recorded postoperatively. The time for visible contrast in extraosseous veins remained essentially unchanged (Table 1).

DISCUSSION

The level of the intraosseous pressure in the femoral neck in the nonarthrotic hip has been reported by Arnoldi et al in 1971 (mean 18.7 mmHg, range 12.9-23.5 mmHg, $n=11$). The normal pressure in the greater trochanter was reported by Arlet et al in 1968 (mean 17.2 mmHg,

THE EFFECT OF FENESTRATION ON INTRAOSSEOUS DRAINAGE IN OSTEOARTHRITIS OF THE HIP

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Eight patients with osteoarthritis of the hip, rest pain and intraosseous hypertension of the proximal femur obtained ameliorated rest pain and reduced intraosseous hypertension 3 months after a fenestration operation in the region of the greater trochanter. They were investigated with intraosseous phlebography of the proximal femur. Six patients showed delayed intraosseous drainage and 7 had altered patterns of drainage before the operation. Three months after the operation the phlebograms showed an even more prolonged drainage time. However, this difference was not of a statistically significant magnitude. Drainage patterns remained mainly unchanged.

Key words: fenestration, intraosseous phlebography, intraosseous pressure, osteoarthritis.

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In osteoarthritis of the hip, venous drainage from the proximal part of the femur is delayed and often shows an altered pattern with dilated intraosseous vessels and diaphyseal sinusoids (Phillips 1966, Arnoldi et al 1972). Arnoldi et al (1971) considered venous engorgement with stasis and intramedullary hypertension to be a probable cause of the rest pain frequently present in this disease. After osteotomy with subsequent relief of rest pain, a "normalization" of the intraosseous blood drainage has been reported by Phillips et al (1967). Recently one of the authors (Åström, to be published) found a significant reduction of the elevated intraosseous pressures in the proximal femur and amelioration of rest pain 3 months after a fenestration operation in the region of the greater trochan-

ter in patients with osteoarthritis of the hip.

The aim of this study was to investigate whether or not amelioration of rest pain and reduction of increased intraosseous pressure in the proximal femur in osteoarthritis of the hip was associated with normalization of routes and speed of intraosseous drainage.

PATIENTS AND METHODS

Eight patients (3 women and 5 men with a mean age of 56 and an age range of 35-72) suffering from osteoarthritis of the hip were selected for this investigation using the criteria of intraosseous hypertension as defined below and rest pain as a dominating symptom. They underwent a fenestration operation in the trochanteric region (Åström 1975). Intraosseous pressure measurements in the femoral head and neck were performed under local anaesthesia a few



*Figure 1 (Patient No 8)
Preoperative phlebogram (2.5 sec
after injection) demonstrating
drainage mainly or all by
intramedullary sinusoids (||→)
Only a few extraosseous veins
(|→) are contrast filled*

range 12-26 mmHg $n=9$). Ficat & Arlet (1972) indicated 30 mmHg as the upper limit of the normal intraosseous pressure in the greater trochanter. Arlet et al (1972) have reported measurements of the intraosseous pressure in the femoral head of normal hips (mean 24 mmHg range 20-30 mmHg $n=4$). No other investigations of the pressure in normal femoral heads have been found in the literature. However in osteoarthritis of the hip the pressure in the head is about 10 mmHg higher than in the neck (Arnold et al 1971, Astrom 1975). In accordance with these investigations we have presumed intraosseous hypertension to be present in the proximal femur when

the pressure of the head was found to be over 40 mmHg and/or the pressure of the neck over 30 mmHg.

Illumination of intraosseous contrast medium in the normal hip was reported to be completed 10 minutes after the injection by Arnold et al (1972) and 5 minutes after the injection by Arlet et al (1971). In our material all patients except one exceeded these limits of "normal" intraosseous drainage time.

The results of this investigation suggest a more pronounced abnormality of drainage time after the fenestration operation but the difference between pre and postoperative investigations is not significant.

Table 1 Intraosseous pressures roentgenological and clinical observations pre and postoperatively in 8 patients with osteoarthritis of the hip undergoing fenestration operations

Patient no	Site of injection	Preoperative observations				Postoperative observations							Effect on rest pain ³⁾
		Pressure (mmHg)	Drainage pattern	E ¹⁾	I ²⁾	Drainage time (min)	Pressure (mmHg)		Drainage pattern	E ¹⁾	I ²⁾	Drainage time (min)	
							head	neck					
1	neck	62.4	31.0	++	(+)	4	57.4	23.4	++	(+)	4	20	+
2	head	85.1	65.0	0	++	48	75.6	43.8	+	+	0.3	20	+
3	neck	61.5	21.0	++	(+)	3	38.2	20.0	(+)	++	4	25	+
4	head	49.1	16.2	+	+	6	59.4	32.3	0	++	-	6	+
5	neck	49.0	49.8	(+)	++	15	46.9	54.4	0	++	-	>30	+
6	head	57.0	35.7	++	+	3	31.6	14.7	+	+	3	25	++
7	neck	48.8	57.0	++	0	15	67.5	65.7	++	0	30	-	+
8	neck	65.9	79.0	(+)	++	4	28.9	27.9	(+)	++	10	>30	+

F designates extraosseous drainage and I intramedullary drainage

1) 0 = no contrast flow visible in extraosseous veins
 + = drainage partly by extraosseous veins
 ++ = drainage mainly or all by extraosseous veins
 (+) = a few extraosseous veins filled

2) 0 = no contrast flow visible in intramedullary sinusoids
 + = drainage partly by intramedullary sinusoids
 ++ = drainage mainly or all by intramedullary sinusoids
 (+) = a few intramedullary sinusoids filled

3) + = less pain postoperatively
 ++ = no pain postoperatively



*Figure 1 (Patient No 8)
Preoperative phlebogram (25 sec
after injection) demonstrating
drainage mainly or all by
intramedullary sinusoids (1-2)
Only a few extraosseous veins
(1-2) are contrast filled*

range 12-28 mmHg *n* 9) Ficat & Arlet (1972) indicated 30 mmHg as the upper limit of the normal intraosseous pressure in the greater trochanter. Arlet et al (1972) have reported measurements of the intraosseous pressure in the femoral head of normal hips (mean 24 mmHg range 20-30 mmHg *n* 4). No other investigations of the pressure in normal femoral heads have been found in the literature. However, in osteoarthritis of the hip the pressure in the head is about 10 mmHg higher than in the neck (Arnold et al 1971, Astrom 1975). In accordance with these investigations we have presumed intraosseous hypertension to be present in the proximal femur when

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Elimination of intraosseous contrast medium in the normal hip was reported to be completed 6 minutes after the injection by Arnold et al (1972) and 5 minutes after the injection by Arlet et al (1971). In our material, all patients except one exceeded these limits of "normal" intraosseous drainage time.

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Patient no	Site of injection	Preoperative observations				Postoperative observations				Effect on rest pain 3)				
		Pressure (mmHg)		Drainage pattern		Drainage time (min)	Pressure (mmHg)	Drainage pattern						
		head	neck	E ¹⁾	I ²⁾			E ¹⁾	I ²⁾					
1	neck	62.4	31.0	++	(+)	4	8	57.4	23.4	++	(+)	4	20	+
2	head	85.1	65.0	0	++		48	75.6	43.8	+	+	0.3	20	+
3	neck	61.5	21.0	++	(+)	3	1.5	38.2	20.0	(+)	++	4	25	+
4	head	49.1	16.2	+	+	6	30	59.4	32.3	0	++	-	6	+
5	neck	49.0	49.8	(+)	++	1.5	30	46.9	54.4	0	++	-	>30	+
6	head	57.0	35.7	+	+	3	15	31.6	14.7	+	+	3	25	++
7	neck	48.8	57.0	++	0	15	-	67.5	65.7	++	+	30	-	+
8	neck	65.9	79.0	(+)	++	4	30	28.9	27.9	(+)	++	10	>30	+

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 (+) = a few intramedullary sinusoids filled

3) + = less pain postoperatively
 ++ = no pain postoperatively

of a lack of reaction to pain as a limiting factor to the rate of injection in their preoperative examination. This factor is of great importance since most patients with intraosseous hypertension experience intense pain during rapid intraosseous injection of fluid.

Our findings do not support the assumption (which was the original reason for this work) that ameliorated rest pain and decreased intraosseous pressure in the proximal femur after fenestration in osteoarthritis of the hip are associated with a normalization of intraosseous blood drainage in the proximal femur.

REFERENCES

- Arlet J, Ficat P & Durrux R (1971) Formes anatomiques (radiologiques et étiologiques) de l'ischémie chronique et de l'ostéonécrose dites primaires de l'épiphyse fémorale supérieure. *Rev Rhum* 38 41-49.
- Arlet J, Ficat P, Lartigue G & Tran M A (1972) Recherches cliniques sur la pression intra osseuse dans la métaphyse et l'épiphyse fémorales supérieures chez l'homme. *Rev Rhum* 39 717-723.
- Arlet J, Ficat P & Sebbag M (1968) Intérêt de la mesure de la pression intra médullaire dans la massif trochantérien chez l'homme en particulier pour le diagnostic de l'ostéonécrose fémoro capitale. *Rev Rhum* 35 250-256.
- Arnoldi C C, Lempert H H & Linderholm H (1971) Immediate effect of osteotomy on the intramedullary pressure of the femoral head and neck in patients with degenerative osteoarthritis. *Acta orthop scand* 42 357-365.
- Arnoldi C C, Linderholm H & Müssbichler H (1972) Venous engorgement and intraosseous hypertension in osteoarthritis of the hip. *J Bone Jt Surg* 54 B 409-421.
- Ficat P & Arlet J (1972) Coxopathies ischémiques. *Rev Chir Orthop* 58 543-561.
- Phillips H H (1966) Phlebography in osteoarthritis of the hip. *J Bone Jt Surg* 48 B 280-288.
- Phillips R S, Hulmer J H, Hoyle G & Davies W (1967) Venous drainage in osteoarthritis of the hip. A study after osteotomy. *J Bone Jt Surg* 49 B 301-309.
- Astrom J (1972) Perioperative effect of fenestration upon intraosseous pressure in patients with osteoarthritis of the hip. *Acta orthop scand* 46 963-967.

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Figure 2 (Patient No 1)
*Preoperative phlebogram (30 sec
 after injection) demonstrating
 drainage mainly by extraosseous
 veins (|→) Some intramedullary
 sinusoids (||→) are also
 contrast filled*



In their study of venous drainage after osteotomy, Phillips et al (1967) assumed intramedullary hypertension by venous congestion to be the cause of rest pain in osteoarthritis of the hip. They found a normalization of venous drainage 12–20 months after intertrochanteric osteotomy and therefore suggested amelioration of pain to be a consequence of the reduced venous congestion. In contrast to the observations of Phillips et al, we were not able to record a similar normalization of venous drainage after fenestration in spite of reduced intraosseous hypertension and ameliorated rest pain. The results of this study therefore do not support the hypothesis of a causal connection between impaired venous drainage and intraosseous hypertension. The dis-

crepancy between the observations of Phillips et al and ours concerning the venous drainage pattern in patients with postoperative amelioration of pain might be explained by the following differences. Firstly, there is the difference in the time interval between operation and postoperative phlebography. Secondly, there is a difference in anaesthetic technique in the study by Phillips et al who used general anaesthesia in preoperative examinations but local anaesthesia in the postoperative ones, whereas we used local anaesthesia in both preoperative and postoperative investigations. This difference in anaesthetic technique also constitutes a possible difference in the speed of injection of contrast medium pre- and postoperatively in the study by Phillips et al because

such as special clothing, changes in operation technique, double surgical gloves, etc. This renders the evaluation of a separate measure like ventilation difficult.

In this paper a bacteriological and epidemiological study will be reported which was undertaken in the operation suite of a department of orthopaedic surgery during operations of total hip replacement. Special attention was given to transmission of infection in connection with operation.

PATIENTS AND METHODS

Patients

One hundred and forty nine patients were subjected to total hip replacement with the Charnley prosthesis from 1972 to 1974. In 34 patients, double sided replacement was carried out. Altogether 163 hip replacements were thus performed. The majority of the patients were over 60 years of age. The number of males and females was about the same. The shortest observation period was one year and the longest three years. For 77 patients the observation period was more than two years.

Bacteriological investigation

During the investigation period routine samples from nose and throat were taken once a week from all operating staff. Specimens were taken from all patients with clinical signs of wound infection and on re-operation.

Prospective study

Fifty four patients were included in a prospective study. On the day of operation samples were taken from the throat, nose, perineum and the skin of the forearm of the patients.

During 77 operations four sedimentation plates were placed in different parts of the operation room. The plates were exposed for eight hours.

Cultural technique

All samples were taken with cotton swabs. Before the skin test was carried out the swab was moistened in peptone water. The swabs were transported in agar slants. Stuart transport medium was used for wound specimens.

Nose, throat and skin specimens were cultivated on sheep blood agar plates only. Perineum specimens were also cultivated on phenol red mannitol agar.

Wound samples were cultivated on blood agar plates with and without gentian violet, on haematin agar, phenol red mannitol agar plates, and on anaerobic blood agar plates with the addition of yeast extract, vitamin K, and haemin. The plates were incubated at 37°C and read after 24 and 48 hours. Anaerobic culture plates were observed for five days and culture was performed according to modern techniques (Anaerobe Laboratory Manual 1973).

Sheep blood agar plates were used as sedimentation plates and read after 48 hours incubation. The total number of bacteria and *Staph. aureus* was determined. The number of bacteria-carrying particles/m³ was calculated from the number found on the sedimentation plates assuming a sedimentation rate of 0.3 m/min (Noble et al 1963).

Isolated bacteria were verified according to current techniques. All *Staph. aureus* were phage typed according to Blair & Williams (1961). Resistance to penicillin was determined with the disc diffusion method according to Ericsson & Sherris (1971).

The design of the operation unit

The design of the central part of the suite, i.e., the operation rooms with surrounding area

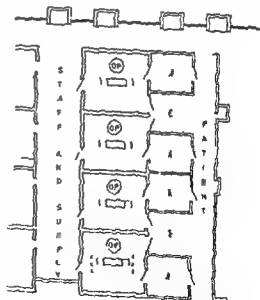


Figure 1 General outline of one block of four operation theatres.

OP Operation room. The room with the broken line is equipped with 'onal ventilation.
A Anaesthetic room.
F Exit area.

AIRBORNE CONTAMINATION AND POSTOPERATIVE INFECTION AFTER TOTAL HIP REPLACEMENT

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GUNNAR LAURILL

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The results of 163 hip replacements at the Uppsala University Hospital are presented. Deep infection occurred in ten cases and was caused by *Staphylococcus aureus* in four early or intermediate infections and by anaerobes in four late infections. The remaining two infections (both of which were late) were probably associated with *Staphylococcus albus*—in one case possibly also with alpha streptococci. Two superficial infections not affecting the operative result were caused by *Staphylococcus aureus* and beta-haemolytic streptococci. The results of environmental analyses of staphylococci and the total number of bacteria in the air during 77 operations did not indicate that airborne infection is a major cause of postoperative infections—there was no difference between the number of bacteria found in the air during operations after which infection occurred and uninfected operations, and the use of special zonal ventilation with high rates of air exchange in the operating area had no effect on the infection frequency.

Key words airborne bacteria, arthroplasty of hip, postoperative infection, ventilation

Accepted 23 xi 76

Hospital infections have again been the object of much attention and intensive debate. However, surprisingly little is known as yet about the real significance of various ways of transmission and what the most suitable control measures should be.

This subject has been much discussed in orthopaedic surgery, particularly in cases of deep infection after total hip replacement. The frequency of infection varies in different investigations from only a few per cent up to 12 per cent or more (Charnley & Eftekhari 1969, Am-

stutz 1970, Lindberg 1976). According to Charnley (1972) this infection is mostly airborne and transmission takes place in connection with the operation, in operation suites with conventional ventilation it is hardly possible to have less than four per cent deep infections, but if "ultra clean air" ventilation is introduced it is possible to reduce the incidence to below one per cent (Charnley 1964, 1972, Charnley & Eftekhari 1969, Eftekhari 1973). During the years that Charnley has carried out his tests he has, however, also introduced other protective measures,

Number of operations
environmental study

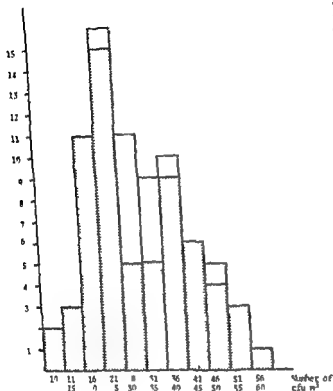


Figure 3 Open bars operations performed in rooms with conventional ventilation Shaded bars operations performed in rooms with zonal ventilation

staphylococci all had different phage patterns

Case 4 was an intermediate onset infection where an increase in anti staphylococcal titre indicated the possibility of a staphylococcal infection

Cases 6-10 were all late infections. In 4 cases anaerobic bacteria were isolated in three cases peptococci and in one case propionibacteria

From the two remaining patients with late infections Staph albus was isolated in one case and Staph albus and alpha streptococci in the other. The staphylococci and alpha streptococci in case 10 were isolated on different occasions and their role in the infection is difficult to establish

There were two superficial infections one was caused by beta-haemolytic strep

tococci and engaged the operation wound. The infection was treated with V penicillin and healed. This patient (case 9) later developed a deep infection. The other superficial infection from which Staph aureus was isolated occurred in a pressure wound caused by a plaster cast

B Prospective study Staff

Staph aureus was isolated from the respiratory tract in 43 per cent of the 169 individuals who took part in operations. Phage typing showed that 79.8 per cent of isolated strains were typable. Group I was the most common with 40 per cent followed by group III with 18.9 per cent and group II with 15.8 per cent. Determination of resistance to penicillin

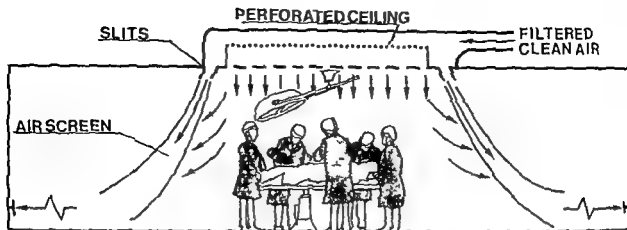


Figure 2 Design of operation room with zonal ventilation

As shown in Figure 1 it can be seen it is a two corridor system in which patients are brought from one of the corridors into the operation room via an anaesthetic room. After operation the patient is transferred to an extubation area which is shared by two operation rooms and then leaves the unit via the same corridor. The other corridor is used by the staff and for incoming clean goods.

There are two ventilation systems for the operation rooms. One is conventional with up to 18 to 20 changes of air per hour. In the other system the main part of the air is introduced above the operation table, a so-called zonal ventilation (Figure 2). A higher exchange of air is thus achieved—about 80 changes per hour in the central part of the room (Abel & Allander 1968).

Criterion of infection

In addition to bacteriological findings the criteria listed by Frieson et al (1973) have been considered.

RESULTS

A Infections

During the study there were ten deep infections involving the area of prosthesis. These cases are presented in Table 1.

Cases 1 to 3 where *Staph aureus* was isolated were early onset infections. The

Table 1 Ten cases of deep infection after total hip replacement

Case no	Sex	Age	Months before sign of infection	Infecting agent	Type of ventilation
1	M	71	0	<i>Staph aureus</i> 6/42E/47/53/54/75/83A	CV*
2	F	15	3	<i>Staph aureus</i> 3 C	CV
3	M	16	2	<i>Staph aureus</i> 29/52	ZV*
4	M	75	6	<i>Staphylococcus</i> ?	ZV
5	F	74	14	<i>Propionibacterium</i> sp	ZV
6	F	54	16	<i>Peptococcus</i> sp	CV
7	M	70	17	<i>Peptococcus</i> sp	CV
8	M	65	19	<i>Peptococcus magnus</i>	ZV
9	M	13	11	<i>Staph albus</i>	ZV
10	F	44	11	<i>Staph albus</i> ? <i>Alpha streptococcus</i> ?	CV

* CV = Conventional Ventilation

ZV = Zonal Ventilation

Number of operations
in environmental study

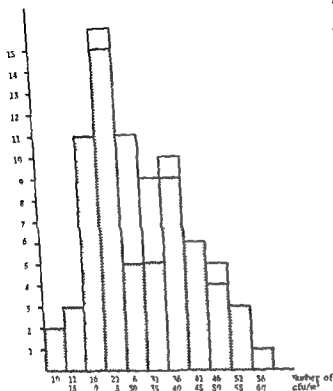


Figure 3 Open bars operations performed in rooms with conventional ventilation Shaded bars operations performed in rooms with zonal ventilation

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II Prospective study Staff

Staph. aureus was isolated from the respiratory tract in 43 per cent of the 169 individuals who took part in operations. Phage typing showed that 79.8 per cent of isolated strains were typable. Group I was the most common with 40 per cent, followed by group III with 18.0 per cent, and group II with 15.8 per cent. Determination of resistance to penicillin

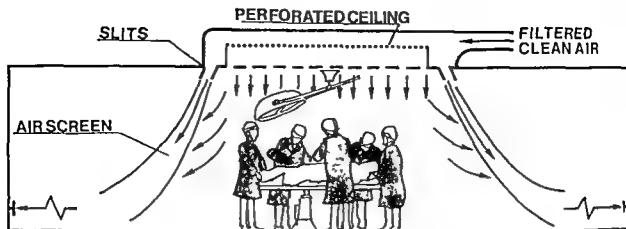


Figure 2 Design of operation room with zonal ventilation

is shown in Figure 1. As can be seen, it is a two corridor system in which patients are brought from one of the corridors into the operation room via an anaesthetic room. After operation the patient is transferred to an extubation area which is shared by two operation rooms and then leaves the unit via the same corridor. The other corridor is used by the staff and for incoming clean goods.

There are two ventilation systems for the operation rooms. One is conventional with up to 18 to 20 changes of air per hour. In the other system the main part of the air is introduced above the operation table—a so-called zonal ventilation (Figure 2). A higher exchange of air is thus achieved—about 80 changes per hour in the central part of the room (Abel & Allander 1966).

Criterion of infection

In addition to bacteriological findings the criteria listed by Ericson et al (1973) have been considered.

RESULTS

A Infections

During the study there were ten deep infections involving the area of prosthesis. These cases are presented in Table 1.

Cases 1 to 8 where *Staph aureus* was isolated were early onset infections. The

Table 1 Ten cases of deep infection after total hip replacement

Case no	Sex	Age	Months before sign of infection	Infecting agent	Type of ventilation
1	M	71	0	<i>Staph aureus</i> 6/42T/47/53/54/75/83A	CV*
2	F	65	3	<i>Staph aureus</i> 3 C	CV
3	M	46	2	<i>Staph aureus</i> 29/52	CV
4	M	75	8	<i>Staphylococcus</i> 8	CV
5	F	74	14	<i>Propionibacterium</i> sp	CV
6	F	54	16	<i>Peptococcus</i> sp	CV
7	M	70	17	<i>Peptococcus</i> sp	CV
8	M	65	19	<i>Peptococcus magnus</i>	CV
9	M	63	13	<i>Staph albus</i>	CV
10	F	44	11	<i>Staph albus</i> ? <i>Alpha streptococcus</i> ?	CV

* CV = Conventional Ventilation
ZV = Zonal Ventilation

ph aureus infection

Patient	Phage pattern of Staph aureus isolated from Staff	Operating theatre	Infection
		29/52	6/42E/47/53/54/75/83A
	29/53/80/88		3C
	52	29/52/77	29/52
	52	NT	
	52/52A		
	52/52A/80		
	NT		
52A/54	29/80	52A/80/54	53/54/77
	6/47/53/54/75/83A	53/54/75	6/47/53/54/75
	3C/55/71	6/47/53/54/75/83A/88	52/52A
	NT		

air in rooms with conventional ventilation. No difference was found in the average number of bacteria between operations followed by infection and uninfected operations.

The occurrence of Staph aureus was low and it was isolated at only 26 out of the 84 operations in the prospective study. The total number of colonies found during the whole investigation was 44 and not more than three colonies were isolated on one operation day. The average occurrence, as estimated from the entire number of operations, was 0.08 c.f.u./m³ air. If the mean value is calculated for operations where Staph aureus was present, it is shown to be 0.25 c.f.u./m³ air.

Possible transmission routes for infections caused by Staph aureus were studied in 13 operations. Staph aureus with the same phage pattern could be isolated from the environment and from the staff. The importance of this with regard to transmission routes in the four patients with Staph aureus infections is demonstrated in Table 2. In case nos 1 and 2 no preoperative cultures were taken from the patients. Among the staff, cultures were taken only from the operating surgeon. In case 1 the infection was caused by staphylococci belonging

to group III with the phage pattern 6/42E/47/53/54/75/83A. The staphylococci isolated from the environment belonged to group I with the phage pattern 29/52. The operator was not a carrier of staphylococci. In case 2 the infection was caused by staphylococci group II with the phage pattern 3C. The surgeon was a carrier of staphylococci but of another phage type. No environmental investigation was made. Case no 3 had a post-operative infection caused by staphylococci group I, phage pattern 29/52. The patient was himself not a carrier of staphylococci. Staphylococci with the same phage pattern were isolated from the air during the operation. In four out of five of the staff taking part in the operation, staphylococci within group I, with a similar phage pattern, were also isolated. The total amount of bacteria was 37 c.f.u./m³ air which is somewhat higher than the mean value. The amount of staph aureus was 1 c.f.u./m³ air which is considerably higher than the mean value 0.08 c.f.u./m³.

The superficial infection was a mixed infection with three different types of staphylococci. The source of one of them was probably the patient, staphylococci with a similar phage pattern were isolated from the patient's respiratory tract.

Table 2 Four cases of

Case no	Staph aureus, c f u /m ³	Total bacteria, c f u /m ³	Carriers of Staph aureus	
			Patient	Staff
1	0.13	23	ND*	See text
2	ND	ND	ND	See text
3	1.0	37	No	5
Superficial infection	0.38	28	Nose-throat + perineum	4

* ND = Not Done

showed that 62 per cent of the strains formed penicillinase

Patients

Respiratory tract Staph aureus was isolated from the nose and throat in 22 of the 84 patients, thus giving a carrier frequency of 26 per cent. The distribution of strains between the various phage groups was the same as for the staff group. Twenty-eight per cent appeared to produce penicillinase.

Skin Staph aureus was isolated from the skin of only two patients. One of them had a strain of the same phage type on the skin as in the nose/throat, whereas the other patient had non-typable Staph aureus on the skin and typable staphylococci in the respiratory tract.

Perineum In eight cases Staph aureus was isolated from the perineum. In six of these Staph aureus was also isolated from the respiratory tract, but in two cases they could only be isolated from the perineum. One of the patients had the same Staph aureus in the respiratory tract, on the skin, and in the perineum. In another two cases the isolated strains were of the same phage type in respiratory tract and perineum, whereas they were of different types in one case.

Strains from three cases were non-typable.

C Environmental investigation

Operation rooms

More operations were carried out in rooms with zonal ventilation than in rooms with conventional ventilation. Since some patients had been treated with antibiotics it was difficult to compare infection frequencies among patients operated on under these different conditions. Of the patients who were not given any kind of antibiotics, 46 were operated on in rooms with zonal ventilation. There were five infections in both groups.

Environmental investigation

The results of the analyses of the air from 77 operations included in the prospective study are shown in Figure 3. As can be seen from the figure, the bacterial content was low in both types of operation rooms. The highest figure was 56 colony-forming units (c f u) of bacteria/m³, and the lowest 10 c f u/m³. The average total amount of bacteria was 31 c f u/m³ in operation rooms with zonal ventilation, measured outside the highly ventilated area, and 30 c f u/m³.

ph aureus infection

Patient	Phage pattern of Staph aureus isolated from Staff	Operating theatre	Infection
	29/53/80/88	29/52	6/42E/47/53/54/75/83A
	52	29/52/77	3C
	52	NT	29/52
	52/52A		
	52/52A/80		
	NT		
52A/54	29/80	52A/80/54	53/54/77
	6/47/53/54/75/83A	53/54/75	6/47/53/54/75
	3C/55/71	6/47/53/54/75/83A/83	52/52A
	NT		

air in rooms with conventional ventilation. No difference was found in the average number of bacteria between operations followed by infection and uninfected operations.

The occurrence of Staph aureus was low and it was isolated at only 26 out of the 81 operations in the prospective study. The total number of colonies found during the whole investigation was 14 and not more than three colonies were isolated on one operation day. The average occurrence as estimated from the entire number of operations was 0.08 c.f.u./m³ air. If the mean value is calculated for operations where Staph aureus was present it is shown to be 0.20 c.f.u./m³ air.

Possible transmission routes for infections caused by Staph aureus were studied in 15 operations. Staph aureus with the same phage pattern could be isolated from the environment and from the staff. The importance of this with regard to transmission routes in the four patients with Staph aureus infections is demonstrated in Table 2. In case nos 1 and 2 no preoperative cultures were taken from the patients. Among the staff cultures were taken only from the operating surgeon. In case 1 the infection was caused by staphylococci belonging

to group III with the phage pattern 6/42E/47/53/54/75/83A. The staphylococci isolated from the environment belonged to group I with the phage pattern 29/52. The operator was not a carrier of staphylococci. In case 2 the infection was caused by staphylococci group II with the phage pattern 3C. The surgeon was a carrier of staphylococci but of another phage type. No environmental investigation was made. Case no 3 had a post-operative infection caused by staphylococci group I phage pattern 29/52. The patient was himself not a carrier of staphylococci. Staphylococci with the same phage pattern were isolated from the air during the operation. In four out of five of the staff taking part in the operation staphylococci within group I with a similar phage pattern were also isolated. The total amount of bacteria was 37 c.f.u./m³ air which is somewhat higher than the mean value. The amount of staph aureus was 1 c.f.u./m³ air which is considerably higher than the mean value 0.08 c.f.u./m³.

The superficial infection was a mixed infection with three different types of staphylococci. The source of one of them was probably the patient, staphylococci with a similar phage pattern were isolated from the patient's respiratory tract.

and perineum as well as from the environment. One of the other types had a pattern similar to staphylococci isolated from one of the operating team and from the environment.

No attempts were made to isolate anaerobic bacteria from the environment and it has therefore not been possible to establish the ways of transmission for these bacteria. The total number of bacteria in one of the anaerobic infections was 42 c f u/m^3 which is higher than the mean value. In one infection the amount was 24 c f u/m^3 air and in two other infections no analysis of the environment were made.

DISCUSSION

During the period of study 10 deep infections occurred. Four were associated with *Staph aureus*. Anaerobic bacteria probably caused four infections. This agrees with the results in some other Swedish reports (Kamme et al 1974). It seems likely that the significance of anaerobic bacteria has been underestimated because of defective isolation techniques.

The environmental investigation showed that the occurrence of *Staph aureus* in the respiratory tract of the staff was 43 per cent which is somewhat above normal, and 20 per cent in patients which is somewhat below normal. Phage typing showed that strains within group I were the most frequent among both staff and patients, but no special phage type was predominant. The frequency of penicillinase-producing staphylococci was nearly twice as high in the staff group.

Air analyses in the operation suites showed that the total number of bacteria was low, the mean was 31 c f u/m^3 and there was no difference between the number of bacteria in operations where post-operative infections occurred and uninfected operations. There was no difference between operation rooms with conventional ventilation and rooms with

zonal ventilation. In rooms with zonal ventilation the determinations were performed outside the "curtain". We have shown experimentally that the relation between the amount of bacteria outside and inside the zone is not less than 2:1 (Hambræus et al 1976). This means that the amount of bacteria inside the zone should have been 15 c f u/m^3 or less. These are low figures and not considerably higher than those found in operation suites with "ultra-clean air ventilation" (Charnley & Eftekhari 1969; Cook & Boyd 1971; McDade et al 1969; Scott 1970).

The amount of *Staph aureus* in the air was very low with a mean value of 0.08 c f u of staphylococci/ m^3 air. In two thirds of the operations no staphylococci were isolated from the air. When *Staph aureus* is isolated from the perineum the risk of transmission is considered to be greater than when it is found only in the respiratory tract. At only one of the eight operations, where the patient was a perineal carrier of *Staph aureus*, was increased transmission to the air established. On the basis of these findings the risk of airborne transmission of staphylococci during operation seems small. Unfortunately, no attempts were made to isolate anaerobic bacteria in the operation environment. It is thus not possible to comment on transmission in these cases.

There was no correlation between the amount of *Staph aureus* in the air and the total amount of bacteria. This is in agreement with other reports and confirms the opinion that the total number of bacteria is not a good indicator of the occurrence of possible pathogenic bacteria in the air (Reid et al 1956; Lidwell 1974; Bourdillon & Colchbrook 1946).

Phage typing of the staphylococci in the operation room showed that in 60 per cent they were of the same phage types as those carried by the staff in the respiratory tract. Only in a few per cent

could the same phage types be found in the patients. For 40 per cent of the staphylococci found in the air the origin could not be established. This can partly be explained by the fact that the air analyses also covered operations other than those belonging to this study. Another explanation is that the staff may carry the staphylococci on their clothes thereby introducing them into the air (Hambræus et al 1976). A comparatively large number of environmental staphylococci were also non typable.

Ventilation does not seem to have affected the incidence of infection to any great extent as the number of postoperative infections was the same in patients operated on in rooms with conventional ventilation and in patients operated on in rooms with zonal ventilation. However, the material is small and does not allow any definite conclusions to be drawn.

The investigation showed that there is a need for comprehensive analyses in order to establish transmission. In the four staphylococcal infections the way of transmission could be explained in two cases. Two were probably airborne and acquired during operation. One of these two patients also had an endogenous infection. In two cases the analysis was too incomplete to allow a final estimation of the way of transmission. When attempting to establish the way of transmission it also seems necessary to study the occurrence of anaerobic bacteria in the operation environment.

Neither the results of environmental analyses of staphylococci nor the total number of bacteria found in this study indicate that airborne infection should have been of any great importance for the observed infections. In two of the 15 operations where *Staph aureus* was found in the environment infection occurred. In this respect the results agree with those of other investigators (Shaw et al 1972) but the problem is controversial and needs further study.

Continued and careful tests will be necessary in order to establish the ways of transmission of all bacteria of importance for these infections and to obtain a better basis for choosing the best prophylactic methods. This is important, especially with regard to the complicated and expensive ventilation systems and other measures that have been introduced for this kind of surgery.

REFERENCES

- Abel E & Allander C. (1966) Undersökning av nytt inblåsningssystem för rena rum. *VIS nr 8*
- Amstutz H C. (1970) Complications of total hip replacement. *Clin Orthop* 72: 123-137.
- Anaerobe Laboratory Manual (1973) Virginia Polytechnic Institute Anaerobe Laboratory Blacksburg Virginia USA.
- Blair J E & Williams R E. (1961) Phage typing of staphylococci. *Bull Wild Dis Org* 17: 771-784.
- Bourdillon R. & Colebrook L. (1946) Air hygiene in dressing rooms for burns and major wounds. *Lancet* 1: 561-601.
- Charnley J. (1964) A clean air operating enclosure. *Brit J Surg* 51: 202-206.
- Charnley J. (1972) Postoperative infection after total hip replacement with special reference to air contamination in the operating room. *Clin Orthop* 81: 167-187.
- Charnley J & Effekhar V. (1969) Postoperative infection in total prosthetic replacement arthroplasty of the hip joint with special reference to the bacterial content of the air of the operating room. *Brit J Surg* 56: 641-659.
- Cook R & Boyd A. (1971) Reduction of the microbial contamination of surgical wound areas by sterile laminar air flow. *Brit J Surg* 58: 48.
- Effekhar V. (1973) The surgeon and clean air in the operating room. *Clin Orthop* 100: 188-194.
- Fricson C, Lidgren L & Lindberg L. (1973) Cloxacillin in the prophylaxis of postoperative infections of the hip. *J Bone Jt Surg* 55A: 803-813.
- Erickson H & Sherris J C. (1971) Antibiotic sensitivity testing. Report of an international collaborative study. *Acta path microbiol scand Sect B Suppl* 217.
- Hambræus A, Bengtsson S & Laurell G. (1976) To be published.

- Kamme, C, Lidgren, L, Lindberg, I & Mårdh, P-A (1974) Anaerobic bacteria in late infections after total hip arthroplasty *Scand J infect Dis* ■ 161-165
- Lidwell, O M (1974) Aerial dispersal of microorganisms from human respiratory tract, p 135-152 In *The normal microbial flora of man* Ed Skinner, F A & Carr, J S, Society for Applied Bacteriology, Symposium series No 3, Academic Press, New York
- Lindberg, L (1976) Personal communication
- McDade, J J, Whitcomb, J G, Whitfield, W. J & Franklin C II (1968) Microbiological studies conducted in a vertical laminar airflow surgery *J Amer med Ass* 203 125-130
- Noble, W C, Lidwell, O M & Kingston D (1963) The size distribution of airborne particles carrying microorganisms *J Hyg (Lond)* 61, 385-391
- Reid, H D, Lidwell O M & Williams R E. O (1956) Counts of airborne bacteria as indices of air hygiene *J Hyg (Lond)* 54 524-532
- Scott, C C (1970) Laminar/linear flow system of ventilation *Lancet* i 989-993
- Shaw, D, Daig, C M & Douglas D (1973) Is airborne infection in operating theatres ■ important cause of wound infection in general surgery? *Lancet* i 17-20

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KNEE INSTABILITY AND TIBIAL OSTEOTOMY

A Clinical Study

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Twenty one gonarthrosis patients were preoperatively assessed according to a newly developed orthoradiographic technique (three point measurement) and followed up for 2-3 years postoperatively using this technique. The medio lateral instability of the knee joints was not influenced by the operation. The varus/valgus deviation was under corrected on average but the deviation did not increase significantly with time after the operation. Judging from this pilot study the three point measurement technique supplies relevant information and it is now being used in a prospective study on high tibial osteotomy in gonarthrosis.

Key words: knee instability, measurement, orthoradiographic method, gonarthrosis, tibial osteotomy.

Accepted 26 viii 76

Since osteotomy of the tibia was first reported by Jackson in 1958 as a method of treatment for gonarthrosis this operation has gained wide acceptance. However preoperatively the size of the wedge to be removed is estimated in many different ways by the various orthopaedic surgeons (Jackson & Waugh 1961, Devas 1969, Harris & Kostelnyk 1970, Coventry 1973). To get a more precise picture of the instability of the knee joint we have devised an orthoradiographic examination method and tested it on healthy subjects (Edholm *et al* 1977).

This paper describes its use in the preoperative assessment of gonarthrosis patients.

METHOD

The orthoradiographic technique was used to examine patients with gonarthrosis before and after the operation. As the varus/valgus deviation of healthy subjects was found to be near zero (Edholm *et al* 1977) we estimated the size of the wedge to be removed so that the deviation after operation would be zero. Thus the size of the wedge should be the same as the deviation determined by the three point measurement technique. A high tibial wedge osteotomy fixed with one or two staples was used. No special effort was made to tighten the collateral ligaments.

MATERIAL

Twenty five patients were operated on. Three died from causes unrelated to the operation and one moved abroad. The remaining 21 patients (13 women, 8 men) with 23 operated knees were followed up for 2-3 years (mean 32 months). Their ages ranged from 47-77 years.

- Kamme, C, Lidgren, L, Lindberg, L & Mårdh P-A (1974) Anaerobic bacteria in late infections after total hip arthroplasty *Scand J infect Dis B* 161-165
- Lidwell, O M (1974) Aerial dispersal of microorganisms from human respiratory tract, p 135-152 In *The normal microbial flora of man* Ed Skinner, F A & Carr, J S, Society for Applied Bacteriology, Symposium series No 3, Academic Press, New York
- Lindberg, I (1976) Personal communication
- McDade, J J, Whitcomb J G, Whitfield, W J & Franklin, C R (1968) Microbiological studies conducted in a vertical laminar airflow surgery *J Amer med Ass* 203 125-130
- Noble, W C, Lidwell, O M & Kingston D (1963) The size distribution of airborne particles carrying microorganisms *J Hyg (Lond)* 61, 385-391
- Reid, D D, Lidwell, O M & Williams R E O (1956) Counts of airborne bacteria as indices of air hygiene *J Hyg (Lond)* 54 524-539
- Scott, C C (1970) Laminar/linear flow systems of ventilation *Lancet* i 989-993
- Shaw, D, Doig, C M & Douglas D (1973) Is airborne infection in operating theatres an important cause of wound infection in general surgery? *Lancet* i 17-20

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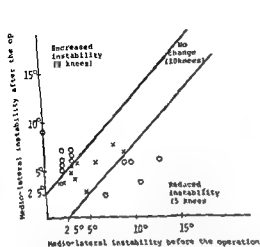


Figure 3 The medio lateral instability of the 23 knee joints before and a short time after the operation \circ = changed and \times = unchanged instability

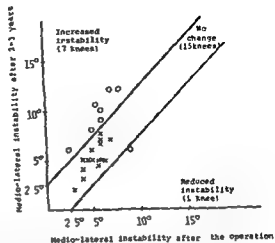


Figure 4 The medio lateral instability of the 23 knee joints a short time and 2-3 years after the operation \blacksquare = changed and \times = unchanged instability

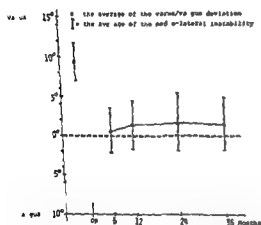


Figure 5 The average of the varus/valgus deviation and the medio lateral instability of the 23 knee joints as they change with time after the operation

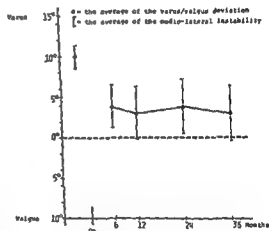


Figure 6 The varus/valgus deviation and the medio lateral instability as they change with time in 10 undercorrected knees (Undercorrected = initial postoperative varus deviation $> 2^\circ$)

Table 2 The patients overall judgement of the operation

Symptoms after the operation				78 %
Much better	"	"	22 %	
Better	"	"	17 %	
Unchanged	"	"	9 %	
Worse	"	"	13 %	

part satisfied with the results of the operation (Table 2)

DISCUSSION

With the three point measurement technique we are able to determine the size of the wedge in a standardized way. It

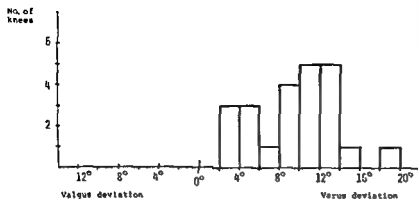


Figure 1 The distribution of the varus/valgus deviation of the 23 knee joints before the operation

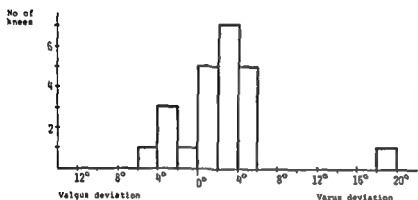


Figure 2 The distribution of the varus/valgus deviation of the 23 knee joints after the operation

(mean 64 years) All the patients had a medial gonarthrosis and thus a valgus osteotomy was done on all the patients

RESULTS

The varus/valgus deviation was corrected in most cases by the operation but one knee was grossly undercorrected (Figures 1 and 2). The medio-lateral instability was as a rule not influenced by the operation (Figures 3 and 4). Taken as

an average the varus/valgus deviation was undercorrected and increased slightly with time (Figure 5), but was within the uncertainty factor of the orthoradiographic method. One would expect the varus/valgus deviation to increase with time in under- or over-corrected knees (Figures 6 and 7) but this did not occur. The pain on loading the knee joint, pain at rest and pain when starting to walk were reduced to various degrees (Table 1) and the patients were for the most

Table 1 Subjective symptoms before and after the operation

Symptom	Before operation	After operation			
		None	Less	Unchanged	Worse
Pain on loading	23 (100 %)	12 (52 %)	11 (26 %)	5 (22 %)	0
Pain at rest	19 (83 %)	18 (78 %)	2 (9 %)	1 (4 %)	2 (9 %)
Pain on starting to walk	20 (87 %)	9 (39 %)	8 (35 %)	3 (13 %)	3 (13 %)

ARTHROPLASTY OF THE KNEE IN OSTEOARTHRITIS AND RHEUMATOID ARTHRITIS

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147 cases of arthroplasty of the knee were reviewed. Three types of prostheses were used *viz.* St. Georg Geomedic and hinge (Shier and Guépar). Pain was the most common indication for the operation which produced complete or almost complete relief in 90 per cent of the cases. In half of the joints with a mobility of less than 80 degrees preoperatively, the range of movement was increased to more than 80 degrees by the operation. Lack of extension, deformity and instability could be largely corrected. Two cases of deep infection were observed both in patients treated with a hinge prosthesis. In one of them the complication led to amputation above the knee and in the other to arthrodesis.

Key words: arthroplasty, knee joint, osteoarthritis, rheumatoid arthritis

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In recent years arthroplasty has been used more often in the treatment of osteoarthritis (OA) and rheumatoid arthritis (RA) of the knee. A wide variety of prostheses have been designed and new ones are continually appearing. So far, however, no ideal type of prosthesis for all cases has been developed, the results of which is that a wide range of indications requires a selection of several types of prostheses. This paper reports the indications and results achieved with three different prostheses at the Department of Orthopaedic Surgery in Malmö

(seven knees) had died. The remaining 113 were

had rheumatoid arthritis (RA). The mean age of the former group was 69 years (range 52-83) and that of the latter 62 years (range 43-77). The mean follow up of the former group was 21 months (1-40) and of the latter 16 months (1-44). The types of prostheses used in these patients and the follow up time are shown in Tables 1a and b. The St. Georg prosthesis was used only in cases of OA in which the medial, and occasionally the lateral part of the joint was involved (Figures 1a and b). When the OA had affected the lateral as well as the medial part, and in cases of RA, the Geomedic prosthesis was preferred (Figures 2a and b). A hinge prosthesis was used (Shier before March 1973, Guépar after this time) in only those cases with severe instability because of insufficiency of the collateral ligament and/or advanced destruction of the joint (Figure 3a and b). Recommended

PATIENTS AND METHODS

The clinical material consisted of 147 knees of 119 patients operated upon between 1972 and 1975. At the time of the review six patients

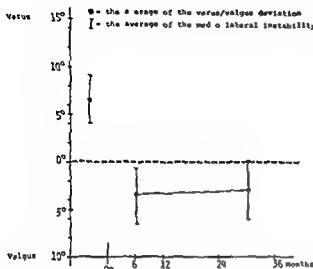


Figure 7 The varus/valgus deviation and the medio lateral instability as they change with time in five overcorrected knees (Overcorrected = initial postoperative valgus deviation $> 2^\circ$)

also allows us to check the results of our operations in a reproducible way. The results in terms of subjective improvement of the patients, with about 80 per cent that benefited by the operation, are the same as in most materials on high tibial osteotomy (Jackson & Waugh 1961, Ahlberg et al 1968, Devas 1969, Harris & Kostuik 1970, Appel & Friberg 1972, Coventry 1973, Hagstedt 1974, Insall et al 1974, Seal & Chan 1975). We therefore conclude from this pilot study that the three point measurement technique gives us relevant preoperative information. We are now using this method

in a prospective study to evaluate the results obtained using different operating principles.

REFERENCES

- Ahlberg A, Scham S & Unander Scham L (1968) Osteotomy in degenerative and rheumatoid arthritis of the knee joint. *Acta orthop scand* 39: 379-388.
- Appel H & Friberg S (1972) The effect of high tibial osteotomy on pain in osteoarthritis of the knee joint. *Acta orthop scand* 41: 558-565.
- Bauer G, Insall J & Koshino T (1969) Tibial osteotomy in gonarthrosis. *J Bone Jt Surg* 51A: 1545-1563.
- Coventry M (1973) Osteotomy about the knee for degenerative and rheumatoid arthritis. *J Bone Jt Surg* 55A: 23-48.
- Devas M (1969) High tibial osteotomy for arthritis of the knee. *J Bone Jt Surg* 51B: 95-99.
- Lidholm P, Lindahl O, Lindholm B, Myrneris R, Olsson K-E & Wennberg K (1977) Knee instability. *Acta orthop scand* 47: 8-63.
- Hagstedt B (1964) High tibial osteotomy for gonarthrosis. ISRN 91: 7222 Of 94 Lund.
- Harris R & Kostuik J (1970) High tibial osteotomy for osteoarthritis of the knee. *J Bone Jt Surg* 52A: 330-336.
- Insall J, Shoji H & Mayer A (1974) High tibial osteotomy. *J Bone Jt Surg* 56A: 1397-1405.
- Jackson J & Waugh W (1961) Tibial osteotomy for osteoarthritis of the knee. *J Bone Jt Surg* 43B: 746-751.
- Seal P & Chan R (1975) Tibial osteotomy for osteoarthritis of the knee. *Acta orthop scand* 46: 141-151.



Figure 2 A 46 year old woman with rheumatoid arthritis before and after arthroplasty of her right knee with a Geomed prosthesis

RESULTS

The effect of the arthroplasty on pain, range of movement and deformity was assessed by comparison between the pre and postoperative state of the knee, according to Freeman et al (1973) (Figures 4, 5 and 6). Complete or almost complete relief of pain was obtained in 90 per cent of the cases. Persistent pain was referable to the patellofemoral joint in most cases. Twelve knees in the OA group and 12 in the RA group were excluded from Figure 5 because the preoperative data were insufficient. In all these cases except one OA case the postoperative range of movement was 80 degrees or more. In those patients in whom the preoperative mobility of the joint was more than 80 degrees this remained the same after the operation. In half of the cases in which the mobility was less than 80 degrees it increased to 80 degrees or more as a result of the operation. In



Figure 3 A 63 year old woman with rheumatoid arthritis before and after arthroplasty of her left knee with a Guepar prosthesis



Figure 1 A 73 year-old woman with degenerative arthritis before and after arthroplasty of her right knee with a St. Georg prosthesis

standard surgical techniques were used (Engelbrecht 1971, Coventry et al 1972, Alnot et al 1971). The operation was performed with a tourniquet above the knee. It was removed before the parts of the prosthesis were cemented. Suction drainage was used for 48 hours after the operation. The leg was placed in a plaster splint for 10 to 14 days. The splint was removed a few hours every day to permit exercise of the quadriceps and gentle movement. Loading of the leg with the splint was allowed from the second postoperative day. To prevent infection the patient was given I kvællin® (1 g/day) for the first postoperative week. Thromboembolic prophylaxis in the form of 500 ml 6 per cent Dextran 70 was given during the operation and again on the second postoperative day.

All the patients were then examined by one (B1) of the authors. The examination included both clinical and roentgenologic evaluation of the knee. The clinical examination comprised assessment of pain, mobility, stability and deformity, as well as walking capacity and the patients' opinions of the results of treatment. Pain was classified according to Freeman et al (1973) as absent, mild (pain which is not spontaneously complained of and which does not require medication), moderate (pain which is spontaneously complained of but which is relieved by simple analgetics) and severe (any

other pain). The stability of the joint was examined with the patient in the supine position and the knee slightly flexed. Both lateral and sagittal instabilities were classified as absent, moderate or severe. Notes were also made of any complications.

Table 1 a Types of prostheses

	St Georg	Geomedic	Hinge	Total
Osteo arthritis	40	25	8	73
Rheumatoid arthritis	0	58	9	67
Total	40	83	17	140

Table 1 b Follow up time

Months	St Georg	Geomedic	Hinge	Total
4-12	2	42	4	48
13-24	15	28	6	49
> 24	23	13	7	43
Total	40	83	17	140

Table 2 Patients' opinion

	Satisfied	Improved	Unchanged	Worse	Total
Osteoarthritis	45	19	1	8	73
Rheumatoid arthritis	60	5	0	2	67
Total	105	24	1	10	140

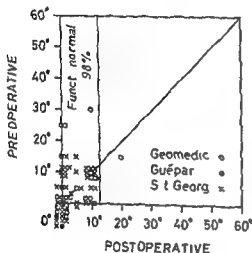


Figure 6a Flexion deformity Osteoarthritis

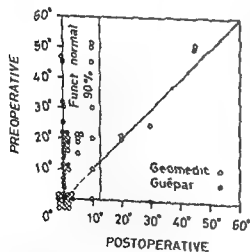


Figure 6b Flexion deformity Rheumatoid arthritis

In the RA group, however, both sagittal and lateral instability were predominant and were sometimes severe. Those patients with moderate instability at the review had no clinical symptoms since correction of valgus or varus deformity had resulted in a favourable distribution of the weight placed on the joint and the joint had been stable when fully extended. The patients' opinions of the results of the operation are given in Table 2.

Complications

A 79 year old woman died from pulmonary embolism two weeks after the operation. The other five deaths occurred long after the operation and were not related to it. The local complications are summarised in Table 3.

Table 3 Local complications

St Georg	1 infection (antibiotics)
Shier (6 knees)	1 infection (above knee amputation)
	1 loosening of the axes (corrected)
Geapar (11 knees)	1 infection (arthrodesis)

The most common local complication was loosening of the prosthesis which occurred in five cases. In all of these it was the tibial part that had loosened.

preoperative condition of the knees were not sufficient to warrant a reliable comparison between the state of the knees before the operation and at the review.

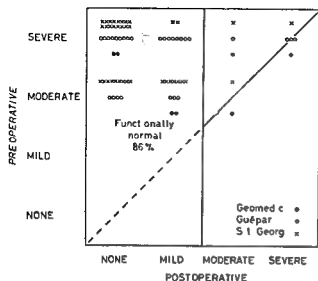


Figure 4a Pain Osteoarthritis

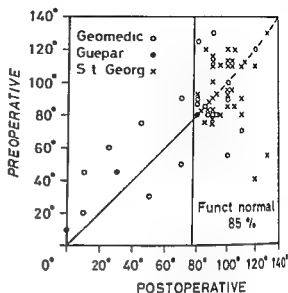


Figure 4b Range of movement Osteoarthritis

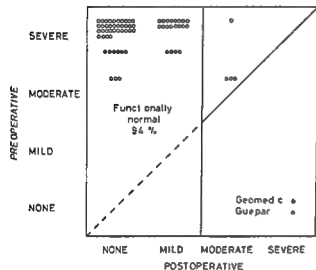


Figure 4c Pain Rheumatoid arthritis

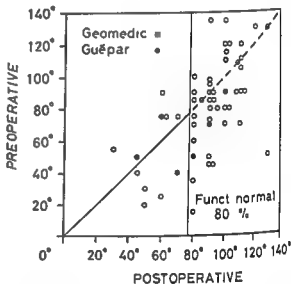


Figure 4d Range of movement Rheumatoid arthritis

eight cases in which mobilisation of the joint was difficult postoperatively, redressment under anaesthesia was made two to four weeks after the operation. Of greater importance than the total range of movement was the fact that in most of the cases extension defects and deformities could be corrected. This was most obvious in the RA patients, who were often severely disabled preoperatively. In Figure 6, nine OA and four RA cases were excluded because of insufficient preoperative data. None of these cases had any flexion deformity postoperatively.

Moderate sagittal instability occurred in five of the 40 knees treated with a St Georg prosthesis and in two of the 58 RA knees treated with a Geomedic prosthesis. Moderate lateral instability was noted in 10 and was severe in one of the 40 patients with a St Georg prosthesis. Of the 25 patients with OA treated with a Geomedic prosthesis, moderate lateral instability was observed in 10. The corresponding figure for the 58 RA knees was 14, plus four in whom the instability was severe. The data about the

Table 2 Patients' opinion

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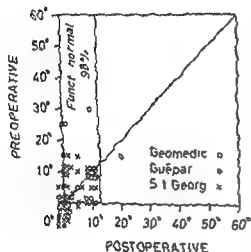


Figure 6a Flexion deformity Osteoarthritis

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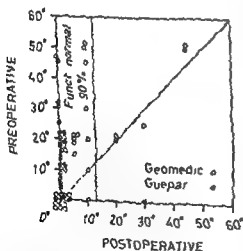


Figure 6b Flexion deformity Rheumatoid arthritis

Table 3 Local complications

St Georg (40 knees)

- 2 loosening of tibial part (replaced by Geomedic)
- 2 malposition of tibial part (corrected)
- 1 suspected infection (antibiotics)

Geomedic (123 knees)

- 2 loosening of tibial part (replaced by Guépar)
- 1 instability (replaced by Shier)
- 1 suspected infection (antibiotics)

Shier (6 knees)

- 1 infection (above knee amputation)
- 1 loosening of the axes (corrected)

Guépar (11 knees)

- 1 infection (arthrodexis)

preoperative condition of the knees were not sufficient to warrant a reliable comparison between the state of the knees before the operation and at the review.

The most common local complication was loosening of the prosthesis which occurred in five cases. In all of these it was the tibial part that had loosened.

These patients were re-operated upon six months to two years after the primary operation. Deep infection occurred in two patients, both operated upon with a hinge prosthesis. One of these, a 52-year-old man with a Shier prosthesis, required amputation above the knee. The stump healed well and the patient has a prosthesis that functions well. The other patient, an elderly woman with a Guépar prosthesis, had an arthrodesis. Two cases of suspected infection were treated with antibiotics. No signs of infection were seen at the review. Neither rupture of the wound nor marginal necrosis was seen in any of the patients.

DISCUSSION

The different types of prostheses available for replacement of half of the joint are so alike that it seems immaterial which type is chosen. The reason why the Geomedic prosthesis was preferred to the double St. Georg prosthesis was because it was thought to be technically easier to obtain a good fit between two parts than between four. In addition, the Geomedic prosthesis has the advantage that its design prevents sagittal instability and lateral or medial dislocation, an advantage of great importance in the treatment of patients with RA.

The hinge prosthesis was used only in cases of a severe instability and deformity. During the former part of the period covered by the investigation the Shier prosthesis was used, but this was gradually superseded by the Guépar prosthesis

which requires less resection of the bone and leaves the patella intact. The hinge prosthesis requires opening of the tibial and femoral medullary cavity and in the event of complicating infection, the prospects of securing arthrodesis are not as good as after the use of other types of prostheses.

The follow-up time was, in about one third of the cases, 4 to 12 months and in about another third more than two years. No significant difference in the results was observed related to period of follow-up time. However, the possibility of further complications such as late infection and loosening must be stressed. All complications observed in this series were diagnosed within 2 years after operation. A direct comparison with other materials is difficult because these usually deal with only one type of prosthesis.

REFERENCES

- Alnot, J. Y., Aubriot, J. H., Deburge, A., Dubousset, J. I., Kenez, C., Mazas, J., Patel, A. & Schramm, P. (1971) Total arthroplasty of the knee. The GUÉPAR prosthesis. *Rev. Orthop.* **57**, 575-581.
- Cosentini, M. B., Finerman, G. A. M., Riley, L. H., Turner, R. H. & Upshaw, J. I. (1972) A new geometric knee for total knee arthroplasty. *Clin. Orthop.* **83**, 157-162.
- Engelbrecht, F. (1971) Die Schlittenprothese eine Teilprothese bei Verstorungen im Kniegelenk. *Der Chirurg* **42**, 510-514.
- Freeman, M. A. R., Swanson, S. A. V. & Todd, R. C. (1973) Total replacement of the knee using the Freeman Swanson knee prosthesis. *Clin. Orthop.* **94**, 153-170.

AMPUTATION AND PROSTHETIC FITTING IN A PATIENT WITH GUÉPAR ENDOPROSTHESIS

TADFLSZ PARADISTAL

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Ischaemic gangrene of the foot in a patient previously fitted with an arthroplasty of the knee (Guépar) was treated with below knee amputation. The endoprosthesis was retained and the patient was fitted with a modified PTB prosthesis. The functional result is satisfactory.

Key words: amputation, arthroplasty, knee joint, prostheses.

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Knee arthroplasty is an increasingly common operation in routine orthopaedic practice. Most of the patients are elderly and one must reckon with the risk that at a later date peripheral circulatory disturbance will necessitate ipsilateral leg amputation.

This problem arose in a 54 year old woman with severe chronic rheumatoid arthritis. She was virtually confined to a wheelchair until 1970 when bilateral Rinz arthroplasty of the hips enabled her to walk with the aid of crutches and to work as a telephonist.

Progressive involvement of the knees however produced destruction of the articular surfaces and contractures. Once more she became chairbound. Bilateral Guépar arthroplasty was therefore performed early in 1973. Remobilization was uncomplicated.

About four months after the Guépar operations she was fit to resume work but she wanted to go to Spain on an organized holiday for disabled persons. After 2 weeks in Spain she became ill with rapidly developing paralysis, anaesthesia and pain particularly in the

legs. She returned to Sweden and examination at this clinic revealed rheumatic polyneuritis with symmetrical peripheral paralysis and impaired sensitivity.

In consultation with rheumatologists the patient was immediately given immunosuppressive agents and cortisone. Two days later however signs of peripheral circulatory insufficiency appeared in the left foot and she was transferred to the rheumatological unit. Despite energetic measures including pressure chamber therapy the foot became gangrenous and she was returned to the orthopaedic clinic for amputation.

The decision to attempt below knee amputation was based on the functional outlook. The expected functional handicap was incomparably less than that entailed by an above-knee amputation and the good function in the endoprosthesis indicated favourable prospects for weight bearing and control of the prosthesis. In this decision the patient concurred.

On November 11 1973 the left lower leg was amputated according to Burgess (1969). The tibia was divided about 16 cm distal to the tibial plateau. The mar-

These patients were re-operated upon six months to two years after the primary operation. Deep infection occurred in two patients, both operated upon with a hinge prosthesis. One of these, a 52-year-old man with a Shier prosthesis, required amputation above the knee. The stump healed well and the patient has a prosthesis that functions well. The other patient, an elderly woman with a Guépar prosthesis, had an arthrodesis. Two cases of suspected infection were treated with antibiotics. No signs of infection were seen at the review. Neither rupture of the wound nor marginal necrosis was seen in any of the patients.

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DISCUSSION

Circulatory disturbance with ischaemic gangrene of the foot below a total knee prosthesis may be in future a not unusual combination. Below-knee amputation can offer a solution in these cases, provided that the arthroplasty is functioning satisfactorily. A relatively long tibial stump must be left to fit under the shaft and cement of the prosthesis, but a dorsal flap should cope with the skin problem in most cases.

The reason why this patient was not initially fitted with an ordinary PTB prosthesis with cuff suspension was the fear of excessive strain on the fixation of the endoprosthesis, particularly in lateral and rotatory movements. The justifica-

tion of this decision remains an open question. The favourable experience with the bathing prosthesis indicates that the ordinary type might have functioned equally well.

In elderly or severely disabled persons, however, relatively little knee function is lost if a PTB is supplemented with double bars and corset. Moreover, the discrepancy between the lower-leg prosthesis and the knee function is less than in ordinary amputation cases, since the Guepar prosthesis also has only a simple rotatory axis.

REFERENCE

- Burgess E M & Zettl J H (1969) Amputations below the knee. *Artificial Limbs* 13: 1-12.

Correspondence to: Tadeusz Paradyski, Dept of Orthopaedic Surgery, Central Hospital, Eskilstuna, Sweden.



Figure 1 Amputation stump



Figure 3 Roentgenogram of the amputation stump with PTB prosthesis

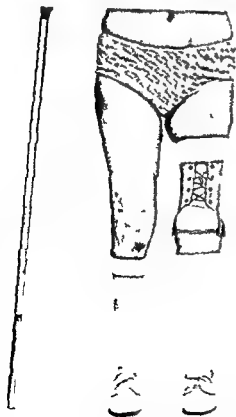


Figure 2 The patient with the prosthesis

row at that point appeared to be normal. The amputation wound healed normally within 3 weeks (Figure 1). After 3 more weeks the first prosthesis was fitted. It was a combination of PTB with double bar and thigh corset (Figures 2 and 3). The right foot was simultaneously fitted with an extension bar to correct persistent foot drop.

The patient rapidly became ambulant. Aftercare was given at the rheumatologic unit. Her general health improved and after some time a light bathing prosthesis of the ordinary PTB type was fitted which enabled her to walk for short distances by the pool. At check-up more than 6 months after the amputation she was walking—as preoperatively—with two crutches. She had no discomfort from the stump and had resumed work as a telephonist.

DISCUSSION

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REIMPLANTATION OF A TRAUMATICALLY EXPELLED TIBIAL DIAPHYSIS

L I HANSSON, C-H HYBBINETTI & L-O SJÖSTRAND

Department of Orthopaedic Surgery, University Hospital Lund, Sweden

The successful reimplantation and healing of a traumatically expelled tibial diaphysis in a 16 year old boy is presented. Radionuclide scintimetry with ^{87m}Sr and ^{85}Sr during the following months showed a pronounced diaphyseal activity corresponding to abundant periosteal bone formation around the dead cortical bone, increased activities over the fractures and the growth plates. Microscopical investigation after tetracycline labelling about 1 year after the accident showed a pronounced osteoblastic and osteoclastic activity in the superficial part of the cortex of the reimplanted bone. The endosteal part consisted of necrotic bone and was only to a small extent replaced by new bone. The uncomplicated healing process observed in this case can be attributed to the youth of the patient, the absence of infection and most important of all, the preservation of the periosteum and its blood supply.

Key words: bone regeneration, bone resorption, fractures, histology, oxytetracycline, reimplantation, strontium radiolabels.

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The management of excessive traumatic loss of cortical bone is a difficult problem. The use of autogenous transplants, artificial devices, as well as reimplantation of expelled pieces of bone (Strange 1963, Kirkup 1965, Abell 1966) has been described. The preoperative handling of expelled bone has also been discussed (Burwell 1969, Imamatov 1969). However, to our knowledge successful reimplantation of a large, full width piece of the tibial diaphysis has not been reported previously. The reorganization of the reimplanted bone was studied by radiography, scintimetry and microscopy.

CASE REPORT

Clinical course

A boy aged 16 years riding his motorcycle collided with a lorry in December 1973. On ad-

mission to a nearby hospital he had a large wound over the right tibia and a 15 cm long piece of expelled tibial diaphysis was found in his trousers. He also had a closed fracture of his right femoral shaft. The initial therapeutic suggestion was to perform an amputation but as the circulation and nerve supply of the limb were intact the surgeons contacted the central orthopaedic clinic. The boy was given high doses of penicillin and tetanus toxoid and the expelled bone was placed in a container with sterile Ringer solution. The boy and the bone fragment were then immediately sent to us a journey of 1½ hours. On admission here the boy was in good general condition. He had a 25 cm long clean wound on the anterior side of the lower leg and the transverse ends of the tibia could be seen in the proximal and distal ends of the wound. The 15 cm long bone fragment comprised the whole missing part. Radiographs showed absence of the tibial shaft (Figure 1) but intact knee and ankle joints.

An operation was immediately performed. The loose bone fragment was carefully cleaned, re-

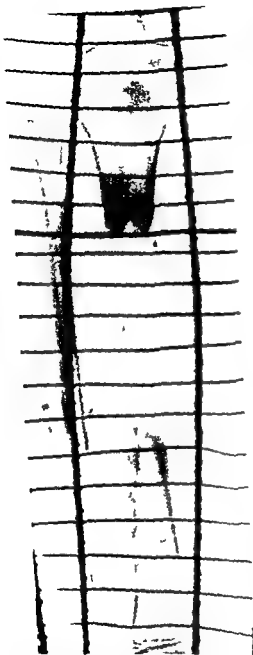


Figure 1 Radiogram on admission. Traumatic loss of 13 cm of the tibial diaphysis. The fractures are transverse. Note shortening of the leg as compared with Figure 2.



Figure 2 Radiograms 2 weeks after reimplantation and nailing of the expelled tibial diaphysis. Early signs of periosteal bone formation.

in a plaster. Postoperatively, a slight valgus deformity (Figure 2) was partially corrected with closed reduction.

Ten days after the accident the femoral shaft fracture was operated on and fixed with plate and screws. Healing of this fracture was uncomplicated.

The postoperative course was remarkably uneventful. He received 8 million international units of penicillin daily for 4 weeks. The wounds healed without signs of infection. After 6 weeks he returned home. After 2 months a PTB plaster was applied (Figure 3). Full weight bearing was allowed after 3 months. After 4 months he could walk quite well and he could flex his knee 90° . Nine months after the accident knee flexion was quite normal and the boy could run in the forest and play football.

One year after the accident there was no difference in leg length and there was normal motion of the knee and ankle joints. The fractures had consolidated both clinically and radio-

ly. The wound which had ruptured along the entire bone defect was sutured back over the bone. After closure of the wound the leg was immobilized

REIMPLANTATION OF A TRAUMATICALLY EXPELLED TIBIAL DIAPHYSIS

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An operation was immediately performed. The loose bone fragment was carefully cleaned, replaced and fixed with a Rush pin. The periosteal



Figure 5 Fluorescence microphoto Undecalcified transverse section from
 a) periosteal region
 b) middle region and
 c) endosteal region of the cortex Note two fluorescent yellow lines indicating bone apposition between the two injections of oxytetracycline The resorption is prominent in the superficial parts (a and b) but almost absent in the deeper part of the cortex (b and c)



Figure 6 Microphoto Decalcified longitudinal section from
 a) periosteal region
 b) middle region and
 c) endosteal region of the cortex Ehrlich's haematoxylin-eosin Note necrotic as well as living bone in the superficial regions (a + b) Deeper regions are characterized by almost necrotic bone and acellular bone marrow (b + c)





Figure 3 Radiograms 2 months after reimplantation. Abundant periosteal bone formation throughout the total diaphyseal area.

graphically (Figure 4) with a valgus deformity of the right tibia of 10° compared with the left

Microscopical investigation

When the Rush pin was removed a block of bone (Figure 4) was removed from the antero-medial cortex of the formerly extruded piece of diaphysis. One month before this biopsy 250 mg Terramycin® $\times 4$ was given *per os*. Immediately before the biopsy 250 mg Terramycin® was given intravenously.

The specimen of cortical bone was sawn transversely into small pieces. Some of these were fixed in Bouin's solution and decalcified in formic acid (40 per cent) and sodium formate (7 per cent). Transverse and longitudinal sections of this material were made with a thickness of about 12 μ . These sections were stained in Ehrlich's haematoxylin-eosin, Azan and Schmorl's phosphotungstic staining.

The other small pieces of cortical bone were fixed in absolute ethyl alcohol and transverse sections were cut with a rotating saw. The thickness of the sections was about 100 μ . The sections were examined in incident and transmitted light in a fluorescence microscope (Leitz Orthoplan).

The thickness of the antero-medial cortex measured about 5–8 mm. In undecalcified and unstained sections there was a brown colour in the vascular channels of the periosteal areas. This colour was absent in the endosteal areas.

In the cortical bone there was an irregular mesh work of necrotic and vital vascular channels and lamellar bone (Figures 5 and 6).

Both in the light microscopy and fluorescence microscopy there was no periosteal appositional bone formation. The bone tissue immediately beneath the periosteum was partly necrotic and partly vital and newly formed. The latter was

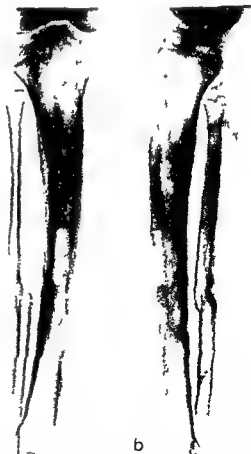


Figure 4 Radiograms 1 year after reimplantation. The Rush pin has been removed and a biopsy has left a cortical defect. Both fractures of the tibial shaft have healed. The abundant bone formation laterally is due to the valgus deformity.

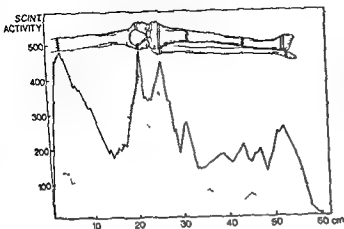


Figure 8 Profile diagram of fractured (—) and normal (---) tibia 2 months after reimplantation. Note the high activities of the growth zones. Generally higher activity in the fractured tibia despite necrotic diaphysis. The localized activity over femur corresponds to the fracture.

Table 1 Mean scintimetry values and indices of areas A-C of the fractured tibia and corresponding values of the normal tibia (within brackets)

	Area A		Area B		Area C		Ref index
	Mean act	Index	Mean act	Index	Mean act	Index	
2 weeks postop	247.4	380.6	121.8	187.3	102.9	158.3	0.65
2 months postop	144.6 (99.1)	267.9 (183.5)	58.1 (30.5)	111.3 (56.2)	46.1 (22.7)	85.4 (42.1)	0.54
9 months postop	-	-	59.0 (27.6)	105.4 (49.5)	-	-	0.56

associated with invaginated vascular channels. Osteoclastic activity was found in both vital and necrotic bone tissue.

In the middle region of the cortex there was an increase in necrotic bone but vital bone was here also found in association with vascular channels. In some regions there was osteoclastic activity of necrotic bone while in other regions there was more appositional bone formation. Most of the vascular channels were made up of ordinary fibrous tissue with many blood vessels. In some of the channels there was necrotic fibrous tissue without signs of osteoblasts and osteoclasts.

The endosteal region showed a 2-4 mm deep zone of mainly necrotic tissue. The osteocyte lacunae were empty. Osteoblasts and osteoclasts as well as osteoid were absent. Most of the vascular channels consisted of an almost acellular fibrous and cystic tissue. Most of the

endosteal surface was necrotic. The marrow cavity was filled with an almost acellular fibrillar tissue but in some areas there were signs of fibroblasts, fat cells and phagocytosis. There was no sign of infection. Some of the veins were occluded by old thromboses without signs of revascularization.

In conclusion the microscopic investigation showed pronounced osteoblastic and osteoclastic activity in the superficial part of the cortex originating from the periosteum and the vascular channels invading the necrotic cortical bone. The lack of actual periosteal bone formation was probably the result of the fact that the biopsy was taken from the antero-medial aspect of the tibia where the load is less.

weight bearing the endosteal regions of the cor-

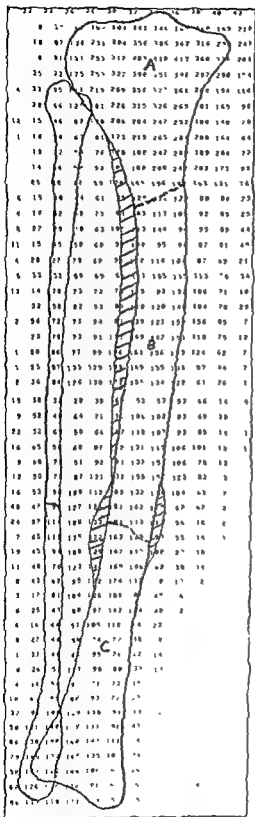


Figure 7a Scintimetry of fractured tibia 2 weeks after reimplantation. Note epiphyseal activities, high activities around the fractures and a pronounced diaphyseal activity corresponding to periosteal bone formation. The bone mass here is dead (B). Shaded area = abun-

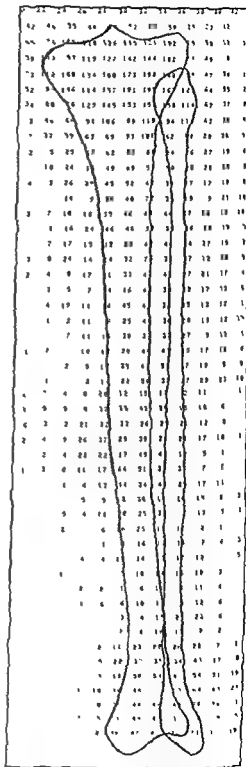


Figure 7b Scintimetry of left intact tibia. Note epiphyseal activities and the difference in comparison with the fractured tibial diaphysis

dant callus formation later seen on radiogram (Figure 3)

tical bone consisted of necrotic bone tissue and were only replaced to a small extent by new bone

Scintimetric investigation

Radionuclide scintimetry was done with ^{87m}Sr at 2 weeks (Figure 7) and 2 months (Figure 8) and with ^{85}Sr at 9 months after the accident. Scintimetry was performed in two ways: (1) with the detector, equipped with a focusing collimator stepwise scanning the entire tibia and fibula in the frontal plane (Figure 7a and b) and (2) with the uncollimated detector moving at a constant height and speed from the groin along the centre of the bone to the foot so that a profile diagram was obtained (Figure 8).

The scintimetries were used for topologic and quantitative definition of the reparative process.

The fractures divided the tibia into three areas (Figure 7a): the proximal (A), the diaphyseal (B) and the distal area (C). After correction for background and soft tissue radiation, the mean values of each area were calculated. For standardization with relation to individual retention and decay, these values were related to a reference index obtained from the normal tibia. Values thus obtained were called activity indexes of areas A-C.

The scintimetry values here are directly related to the accretion rate of the bone tissue (Bauer 1968). The four maxima observed over the tibia correspond to the growth zones and the two fractures (Figures 7a and 8).

In the growth zones the values were 2-3 fold increased, probably reflecting the hyperaemia and overgrowth of a fractured bone.

The high values observed around the fractures also reflected the reparative process. The increased values over the reimplanted bone were more surprising. However, even though the bone was dead, the periosteal reaction was 2-3 times that of the periosteum and bone on the normal side.

DISCUSSION

There are two reasons why an expelled tibial diaphysis should be reimplanted. Firstly, it provides an automatically adequate spacer which preserves the shape and length of the bone during the rebuilding process. Secondly, it is an immunologically compatible substance which acts as a meshwork for the osteoblastic activity, and is capable of being removed gradually so that the physical strength of the bone is preserved. The remarkably swift and uneventful healing process observed in our case can be attributed to the youth of the patient, the absence of infection, and, most important of all, the preservation of the periosteum and its blood supply.

REFERENCES

- Abell C F (1966) Extrusion of femoral shaft fragment by trauma and successful replacement. *J Bone Jt Surg* 48 A: 537-541.
- Bauer G C H (1968) The use of radionuclides in orthopaedics. *J Bone Jt Surg* 50 A: 1681-1709.
- Burwell R G (1969) The fate of bone grafts. In *Recent advances in orthopaedics*. Ed. Apley A G, pp 115-208. Churchill, London.
- Imamshiev A S (1969) The preparation, preservation and transplantation of articular bone ends. In *Recent advances in orthopaedics*. Ed. Apley A G, pp 209-264. Churchill, London.
- Kirkup J R (1963) Traumatic femoral bone loss. *J Bone Jt Surg* 47 B: 106-110.
- Strange F G St C (1963) Union of fractures. *Lancet* 1: 305-307.

Pantazopoulos et al 1974) the 123 fractures of the neck of the talus were radiologically divided into three groups

Group 1 comprised undisplaced fractures through the neck of the talus not involving the ankle joint or subtalar joint (Figure 1)

Group 2 comprised displaced fractures through the neck of the talus with subluxation or dislocation of the subtalar joint but with the trochlea in position in the ankle joint (Figure 2)

Group 3 comprised displaced fractures through the neck of the talus with dislocation of the ankle joint as well as the subtalar joint (Figure 3)

The 123 patients were divided into the three groups as follows: 54 (44 per cent) in group 1, 53 (43 per cent) in group 2 and 16 (13 per cent) in group 3. All 16 patients of group 3 had posterior dislocation of the trochlea.

Simultaneous injuries of the other tarsal and metatarsal bones and of the malleoli are common as well as fractures of other limbs. Sixty patients had other injuries besides fracture of the talus: 35 of these had malleolar fracture and 13 calcaneal fracture. Thus the fracture of the neck of the talus was an isolated injury in only 63 patients (51 per cent).

Table 3 Incidence of avascular necrosis

Alphal group	Fracture of neck of talus No	Avascular necrosis No
Group 1	54 (100%)	2 (4%)
Group 2	53 (100%)	12 (24%)
Group 3	16 (100%)	11 (69%)
Total	123 (100%)	25 (21%)

Initial treatment

All patients of group 1 received conservative treatment; seven were treated with weight re-

lease for 6 to 8 weeks while the remaining 47 had a plaster cast with no weight bearing for 6 to 14 weeks. All group 1 fractures united.

Of the 53 patients in group 2, four were treated by open reduction, 30 by closed reduction followed by plaster cast and no weight bearing. The remaining 19 patients were treated by plaster cast without reduction. The period of plaster fixation and weight release averaged 8 to 12 weeks. Seven of the 53 fractures were open.

In group 3, 11 of the 16 patients were treated by open reduction, one by primary excision of the trochlea, one by primary subtalar arthrodesis and three by closed reduction. Six of the fractures in this group were open.

RESULTS

The long term prognosis is mainly determined by the occurrence of necrosis of the body of the talus, osteoarthritis, and union with deformity or non union.

Osteonecrosis The avascular necrosis of the body of the talus was graded into four groups.

In grade 1 there was a condensation of the bone but no deformity; in grade 2 there was a healed condensed corpus with mild to moderate deformity; in grade 3 there was a healed condensed corpus with severe deformity; and in grade 4 there was sequestration of the trochlea = no healing.

Twenty six of the 123 patients (21 per cent) developed avascular necrosis of the trochlea (Table 3). Seven were of grade 1, 16 of grade 2, two of grade 3 and one of grade 4. It was surprising to find two

Table 4 Occurrence of osteoarthritis, mal union and non union

Alphal group	Fracture of neck No	Talo-crural osteoarthritis No	Subtalar osteoarthritis No	Mal union No	Non union No
Group 1	54 (100%)	8 (15%)	13 (24%)	0 (0%)	0 (0%)
Group 2	53 (100%)	19 (36%)	25 (66%)	15 (29%)	3 (6%)
Group 3	16 (100%)	11 (69%)	10 (63%)	3 (18%)	2 (12%)
Total	123 (100%)	38 (31%)	58 (47%)	18 (15%)	5 (4%)

Table 1 Incidence of avascular necrosis in fractures of the neck of the talus in previous series

	Fracture of neck of talus No	Avascular necrosis No
McKeever 1943	17	12 (71%)
Coltart 1952	106 *	26 (25%)
Sullivan & Jackson 1958	29 **	7 (24%)
Hawkins 1970	52	30 (58%)
Pantazopoulos et al 1974	20	9 (45%)
Lorentzen et al 1976	123	26 (21%)

* Nearly all due to flying accidents during the Second World War

** Fourteen of the patients were children under 16 years. Material not consecutive

PATIENTS AND METHODS

The material for the study has been obtained from the Danish Health Insurance Authority which received, during the period 1945-1972, reports on 218 patients with injuries to the talus, including 123 with fractures through the neck.

For all 123 patients a final specialist report was available, comprising a clinical and a radiological evaluation. These specialist reports together with the case records and X ray films formed the basis of the present study.

The follow-up period, from the time of accident to the final examination, ranged from 7 to 73 months, mean 22 months.

The patient material is representative except for a male predominance, as housewives are generally not insured. Out of the 123 patients, 107 were males and 16 females. The age range was between 9 and 70 years, mean 39 years. Table 2 gives the causes of the injuries.

Table 2 Cause of injury

	Fracture of neck of talus No
Fall	47 (39%)
Direct trauma to the foot	34 (28%)
Distortion	10 (8%)
Traffic accident	31 (25%)
Total	123 (100%)

Classification

In accordance with the conventional classification (Coltart 1952, Watson-Jones 1962, Pennal 1963, Hawkins 1970, Kenwright & Taylor 1970

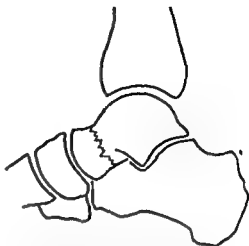


Figure 1 Group 1 fractures. Undisplaced fracture through the neck of the talus. Ankle joint and subtalar joint not involved.



Figure 2 Group 2 fractures. Displaced fracture through the neck of the talus. The subtalar joint is subluxated or completely dislocated. Trochlea in position in the ankle joint.

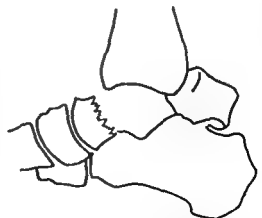


Figure 3 Group 3 fractures. Displaced fracture through the neck of the talus. Talar body displaced in both ankle and subtalar joint.

Five patients exhibited non union of the neck. One also had avascular necrosis of the body. All ended up with severe complaints.

Subjective and objective results In order to assess the prognosis of fractures of the neck of the talus as regards subjective complaints and rehabilitation, we analyzed the 63 patients in whom the talar fracture was an isolated injury.

Table 5 presents the subjective results. It is striking that so many patients with undisplaced fractures had moderate or severe complaints (46 per cent). However, this is in accordance with the large frequency of osteoarthritis in these patients.

Rehabilitation is shown in Table 6. It should be noted that among the patients with undisplaced fractures 10 (33 per cent) were unable to continue in their former occupation. We have also included the degree of disablement as assessed by the Health Insurance Authorities (Table 7).

DISCUSSION

So far the prognosis of undisplaced fracture of the neck of the talus (group 1) has been considered favourable (Collart 1952; Hawkins 1970; Pantazopoulos et al 1974). However, the 34 undisplaced fractures (group 1) in the present material were associated with a considerable incidence of complications comprising two cases of avascular necrosis, eight of talar-crural osteoarthritis and 13 of subtalar osteoarthritis. Forty six per cent had moderate or severe complaints and only 62 per cent could continue in their previous work.

It is well known that the prognosis of displaced fractures of the neck (groups 2 and 3) is poor but this has been attributed to the occurrence of avascular necrosis. Our material shows that even those patients with displaced fractures of the neck who avoid necrosis of the body

run a considerable risk of developing osteoarthritis—especially in the subtalar joint. Of the 40 patients without necrosis of the body, 21 (53 per cent) developed subtalar osteoarthritis.

It is interesting to find a high incidence of talar-crural osteoarthritis in groups 1 and 2 in which the fracture does not involve the ankle joint. It is evident that talar-crural osteoarthritis may occur when the body is necrotic. When subtracting the cases with osteonecrosis, we find the same percentage of cases with talar-crural osteoarthritis (13 per cent) in the three morphological groups, indicating that regardless of which type of fracture of the neck it causes, the trauma exerts violent force upon the ankle joint in which it gives rise to cartilaginous and ligamentous damage. This assumption is supported by the finding that 35 (28 per cent) of the fractures of the neck of the talus were associated with malleolar fractures.

In the literature, the incidence of avascular necrosis following fracture of the neck of the talus has been reported to be from 24 to 71 per cent (Table 1). The high incidence has been reported particularly by authors using small numbers of patients. However, these studies have been predominated by rather severe fractures of the neck and included only a few undisplaced group 1 fractures in which necrosis is rare.

In our material group 1 fractures made up 44 per cent, and the incidence of avascular necrosis proved to be 21 per cent. This agrees with the only large series reported so far (Collart 1952).

REFERENCES

- Collart W. H. (1952) Avascular astragalus. *J Bone Jt Surg* 34 B 545-566.
- Hawkins G. L. (1970) Fractures of the neck of the talus. *J Bone Jt Surg* 52 A 991-1002.
- Kenwright J. & Taylor H. G. (1970) Major injuries of the talus. *J Bone Jt Surg* 52 B 26-48.

Table 5 Subjective complaints in 63 patients with isolated fracture of the neck of the talus

Morphol group	Fracture of neck of talus No	No complaints No	Moderate complaints No	Severe complaints No
Group 1	26 (100%)	14 (54%)	10 (38%)	2 (8%)
Group 2	31 (100%)	7 (23%)	11 (35%)	13 (42%)
Group 3	6 (100%)	1 (17%)	3 (50%)	2 (33%)
Total	63 (100%)	22 (35%)	24 (38%)	17 (27%)

Moderate complaints Light to moderate painful gait walking ability normal or slightly impaired
Severe complaints Severely painful gait with severely impaired walking ability

Table 6 Rehabilitation in 63 patients with isolated fracture of the neck of the talus

Morphol group	Fracture of neck of talus No	Same work No	Lighter work No	Not working No
Group 1	26 (100%)	16 (62%)	8 (30%)	2 (8%)
Group 2	31 (100%)	14 (45%)	14 (45%)	3 (10%)
Group 3	6 (100%)	0 (0%)	5 (83%)	1 (17%)
Total	63 (100%)	30 (48%)	27 (43%)	6 (9%)

Table 7 Degree of disablement in 63 patients with isolated fracture of the neck of the talus

Morphol group	Fracture of neck of talus No	0% No	5-8% No	10-18% No	20-50% No
Group 1	26	5	11	8	2
Group 2	31	1	5	16	9
Group 3	6	0	1	3	2
Total	63	6	17	27	13

cases of osteonecrosis in the group of undisplaced fractures both were grade 2.

Osteoarthritis. About one third of the 123 patients developed talo-crural osteoarthritis whereas one half developed subtalar osteoarthritis (Table 4). Twenty-nine patients (24 per cent) had talo-crural as well as subtalar osteoarthritis. The incidence of talo-crural osteoarthritis was evenly increased in groups 1 and 3 whereas subtalar osteoarthritis was almost unchanged in groups 2 and 3 (Table 4).

All patients with avascular necrosis developed osteoarthritis. Of the seven patients with grade 1 necrosis six developed osteoarthritis of the talo-crural as well as subtalar joint. All 19 patients with grade 2-4 necrosis developed severe talo-crural and subtalar osteoarthritis.

Deformity and non union. Fifteen fractures, all from groups 2 and 3, united with appreciable deformity of the neck (Table 4). A poor subjective result of moderate or severe complaints was obtained from 17 of these 18 patients.

POST-TRAUMATIC SINUS TARSI SYNDROME

An Anatomical and Radiological Study

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Four cases of sinus tarsi syndrome are presented. They were studied by means of arthrography of the posterior subtalar joint and histological examination of sinus tarsi soft tissue. The obliteration of synovial recesses on posterior subtalar joint arthrography can be explained by synovial hyperplasia and by cicatricial remodelling of ligament tissue.

* **Key words:** subtalar joint arthrography, tarsal sinus syndrome, diagnosis.

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The X-ray pictures of patients with sinus tarsi syndrome do not show skeletal changes (Debrunner 1963, Hauser 1962, Navarre 1966, Meyer & Taillard (1974)) have previously described arthrographic changes in the posterior subtalar joint in nine patients suffering from post-traumatic pain in the midtarsal joints. These changes were considered significant since they were not observed in 90 clinically normal subjects. Two of the patients had pain over the lateral part of the sinus tarsi, thus presenting a clinical picture similar to that described by O'Connor in 1966 as "sinus tarsi syndrome". Therefore a clinical and radiological entity of post-traumatic sinus tarsi syndrome was proposed by Meyer & Taillard (1974) on the basis of this association between foot pain (not necessarily confined to the sinus tarsi) and a characteristic arthrographic appearance of the posterior subtalar joint, viz. absence of synovial recesses in front of the interosseous ligament.

The present article describes four cases of this syndrome which were studied anatomically and radiologically.

Normal Anatomy and Radiological Appearance of the Sinus Tarsi

Anatomy. The cohesion of the talus and the calcaneus is ensured by several ligaments, primarily the interosseous talocalcaneal ligament. The latter is attached to the sulcus tali and the sulcus calcanei, which form the roof and floor of the sinus tarsi. The ligament is thinner and more fibrous on the medial side and thicker on the lateral side where its bundles intermingle with fatty tissue (Figure 1). Thus a transversal sheet in the sinus tarsi thus separates the two diarthrodial joints which are found between the talus and the calcaneus. The anterior joint forms part of the talocalcaneo-navicular joint and the posterior one is the actual talocalcaneal or subtalar joint.

- McKeever F M (1943) Fracture of the neck of astragalus *Arch Surg* 46 720-735
- McKeever, F M (1963) Treatment of complications of fractures and dislocations of the talus *Clin Orthop* 30 45-52
- Pantazopoulos Th Galanos P Vayanos E Mitson A & Hartofilakidis Garofalitis G (1974) Fractures of the neck of the talus *Acta orthop scand* 45 296-306
- Pennal G F (1963) Fractures of the talus *Clin Orthop* 30 53-63
- Peterson I (1974) Fracture of the neck of the talus *Disp (Göteborg)*
- Stealy J H (1909) Fracture of the astragalus *Surg Gynaec and Obstet* 8 36-48
- Sullivan C R & Jackson H C (1958) Fracture dislocations of the astragalus in children *Acta orthop scand* 21 302-309
- Symes J (1848) *Contributions to the Pathology and Practice of Surgery* Sutherland and Knox Edinburgh
- Watson Jones R (1962) *Fractures and Joint Injuries* Livingstone London

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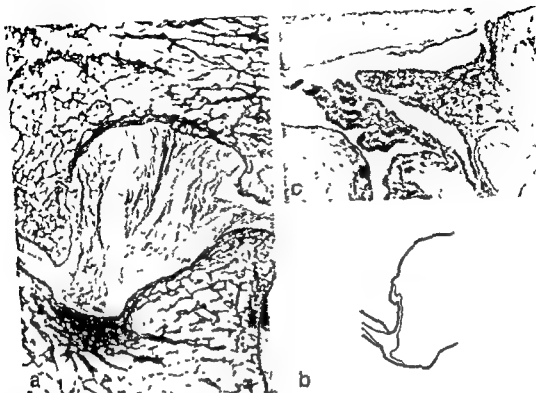


Figure 2 Histology of a normal sinus tarsi (same case as Figure 1)

- Topographical histology (lateral sagittal section—Haematoxylin eosin X 27) Bundles of interosseous ligament separated by adipose tissue Synovial membrane layer on the anterior and posterior surfaces of the ligament with synovial recesses on the latter
- Diagram of the posterior part Thick line, bony contour, thin line, cartilaginous and synovial surfaces
- Hyperplastic synovial fringe on the posterior surface of the interosseous ligament (sagittal section more medial than in (a)—Haematoxylin eosin X 22) On the right, adipose tissue of the ligament On the left cartilaginous talar and calcaneal surfaces

sinus tarsi) was found to contain scar tissue in case 1 and the lateral talocalcaneal ligament

Case 1 showed signs of cicatricial remodelling in the very small fragment of ligament studied. The changes seen in the other three cases were decidedly abnormal and were particularly marked in case 3. The synovial membrane exhibited papillary

hyperplasia (Figure 5) characterized by an abundance of cells in some places and fibrous changes in others, a lack of fibrin deposits, absence of polymorphonuclear or lymphoplasmocytic infiltration except for a few small clusters of lymphocytes (Figure 6a), haemosiderin deposits indicative of old haemorrhages (clear deposits in case 1, faint ones in case 2 and none at all in case 3), and thickening of the adjacent blood vessels. In case 1 some remnants of pre-existing ligaments were embedded in hyperplastic synovial membrane (Figure 6b).

Cicatricial remodelling in the ligament was seen in case 1. In case 2 the ligament was replaced by scar tissue—(Figure 7).

In case 3 the cartilage surfaces showed a mar-

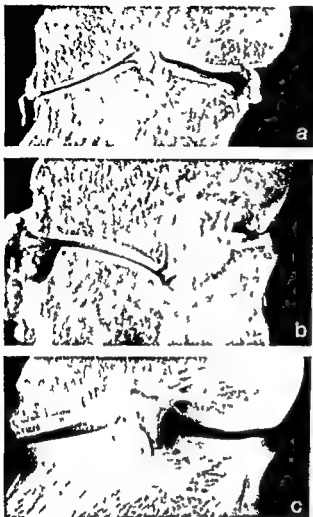


Figure 1 Normal subtalar joint with interosseous ligament (72 year old man with no joint disease). Anterior region is on the right

- a) Macroscopic appearance of a medial sagittal surface
- b) Macroscopic appearance of a lateral sagittal surface
- c) X ray of a central sagittal section (1 cm thick)

Hence, both sides of the interosseous talocalcaneal ligament are lined with synovial membrane. This was observed histologically on sagittal sections of two anatomical specimens taken from subjects with no osteoarthicular pathology. On the posterior side the synovium formed small superior and inferior recesses and occasional papillary folds due to simple hyperplasia of the lining cells (Figure 2). On the anterior side fairly

similar small recesses were observed on certain sections. The synovial membrane lined the remainder of the articular cavity of the posterior subtalar joint, particularly at the level of the well developed posterior, lateral, and medial recesses.

Radiological appearance The soft tissues of the sinus tarsi can be evaluated radiologically only by means of an arthrographic mould. However, arthrography of the talocalcaneo-navicular joint involves technical problems and does not readily permit a study of the sinus tarsi. Arthrography of the posterior subtalar joint was therefore performed as proposed by Meyer (Meyer 1973; Meyer & Taillard 1974), the best view being obtained with an image intensifier. The contrast medium injected into the posterolateral part of the joint cavity formed a thin layer between the calcaneal and talar cartilage surfaces and filled the medial and lateral recesses. It then penetrated into the posterior joint cavity, which on oblique view arthrography, resulted in an opacification of half the surface of the sinus tarsi (Figure 3). By filling small synovial recesses or folds on the posterior side of the interosseous talocalcaneal ligament the contrast medium produced indented images that were clearly visible on transverse arthrographic post mortem sections (Meyer 1973) as well as on lateral view arthrography (Figure 3). Communication with the talocalcaneo-navicular joint was rare.

CASE REPORTS

The clinical details of the four cases studied are given in Table 1. All cases showed the two subtalar arthrographic changes (Figure 4) formerly considered to be characteristic of pathological alteration of the soft tissues of the sinus tarsi (Meyer & Taillard 1974) viz absence of filling of the sinus tarsi and of several small recesses in the lining of the interosseous ligament.

After the failure of medical treatment surgery was performed (Table 1) leading to favourable results in all four cases. During operation the

Table 1 Clinical details of the four cases studied

	Case 1	Case 2	Case 3	Case 4
Sex	male	male	male	male
Age (at biopsy)	25 years	24 years	30 years	47 years
Nature of injury	sprain (left foot) tear of calcaneo fibular ligament	sprain (right foot)	fracture of fibula and malleolus—fracture of calcaneus (left foot)	fracture of os trigonum tear of talo calcaneal ligament
Interval between injury and arthrography	?	2 years 5 months	1 year 10 months	1 year 6 months
Interval between injury and surgery	?	3 years	1 year 11 months	4 years
Intervening symptoms	pain	pain (particularly upon palpation of sinus tarsal)	pain	pain (particularly upon palpation of sinus tarsal)
Nature of operation	plasty of calcaneo fibular ligament sinus tarsal curettage	subtalar arthrodesis sinus tarsal curettage	subtalar arthrodesis sinus tarsal curettage	sinus tarsal curettage
Findings	sinus tarsal contents fibrous capsule with ligament synovial membrane	sinus tarsal contents fibrous capsule with ligament synovial membrane	sinus tarsal contents fibrous capsule with ligament synovial membrane + bone and cartilage	sinus tarsal contents fibrous capsule with ligament synovial membrane
Biopsy number	T 5683/74	T 11432/74	T 10372/73	T 2701/74



Figure 3 Normal arthrography of a posterior subtalar joint (30-year-old man with no joint disease) Oblique lateral view Opacification of half the surface of the sinus tarsi with moulding of small synovial recesses

ginal osteophyte indicating a minor equivalent of osteoarthritic remodelling, the underlying bone showed evidence of discrete non-specific remodelling

DISCUSSION

Studies of the normal histological appearance of the sinus tarsi make it clear why arthrography is valuable in the

diagnosis of soft tissue changes (Figure 2). They enable one to appreciate why remodelling with synovial hyperplasia has to be marked before it can obliterate the radiological images of synovial recesses or fringes. As a result of such studies it can further be understood why such obliteration might also be caused by joint effusion, particularly haemorrhage.

Microscopical observations strongly suggest that trauma can cause remodelling of this kind in the soft tissues of the sinus tarsi. In the cases presented here the changes were quantitatively rather marked and qualitatively similar to those usually seen in post-traumatic conditions (as opposed to the changes seen in infections or rheumatoid illness). Of the analogous histological examinations mentioned in the literature, "inflammatory changes were observed in some of them (Blasnik cited by Komprdá 1966) but not in others (O'Connor cited in Brown 1960 and Komprdá 1966). In the light of our experience, this discrepancy might be due to differences in the quantity and orientation of the material examined. In our opinion, arthrography is not diag-

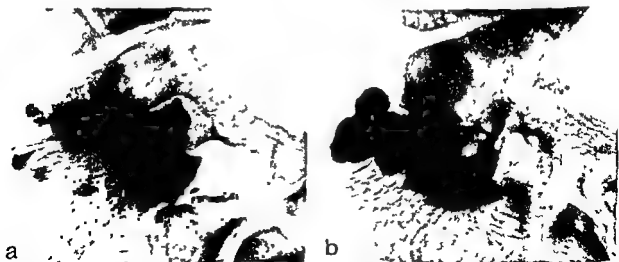


Figure 4 Arthrography of the posterior subtalar joint with pathological changes in the sinus tarsi—oblique lateral view (a) Case 1 (b) Case 2 Partial obliteration of the posterior subtalar joint. Contrast medium is forced to the back. Small synovial recesses are not visible. The lateral and posterior synovial recesses are different in appearance in both cases

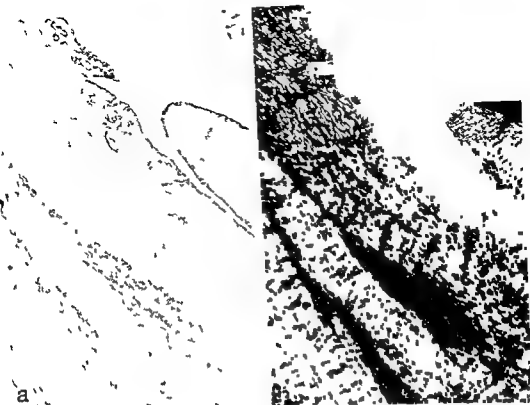


Figure 7 Case 1 Ligament bundles connected to fibrous tissue resulting from cicatricial remodelling

a) Normal light

b) Polarized light showing differences in structure between pre existing ligament bundles (lower left) and fibrous scar tissue (upper right)—(Massaforzlin eosin $\times 22$)

nostically useful immediately after trauma because it is only later on that synovial hyaline is lost.

and cartilage changes observed in case 4 are not visible on X rays but may be considered as early osteoarthritic changes similar to those sometimes seen in the subtalar joint (Brown 1960, Debrun 1963, Kompridis 1966).

These pathological soft tissue changes in the sinus tarsi seem to be secondary mainly to rupture of the calcaneofibular ligament. This was observed clinically in nine cases in a previous study (Meyer & Faillard 1974). In our present case 1, the rupture was observed at operation and

was unassociated with any bone changes. Simple plasts of the ligament resulted in the disappearance of symptoms, which were still absent after 6 months. This is consistent with Castaing's view on the role of the calcaneofibular ligament in subtalar stability (Castaing 1970).

An anatomical and radiological picture of the post traumatic sinus tarsi syndrome is thus recognizable. However, it cannot be superimposed on a characteristic clinical picture. For example, in case 1, which was radiologically and histologically typical, there was rather diffuse pain in the mediotarsal region and no elective pain over the sinus tarsi. Conversely, a post traumatic syndrome featuring just such pain has been observed



Figure 5 Case 1 Synovial hyperplasia without inflammatory cells

- a) Overall topographical view with underlying sub-synovial tissue (Haematoxylin eosin $\times 25$)
 b) Detail (Haematoxylin eosin $\times 75$)



Figure 6 Case 1 a) Synovial fringe Hyperplasia with inflammatory cells with a small cluster of lymphocytes (Haematoxylin eosin $\times 180$)
 b) Synovial fringe Hyperplasia with fibroblastic hyperplasia above right fibrous scar tissue which includes some remnants of ligament this reflects the destruction of pre-existing tissue (Van Gieson $\times 180$)

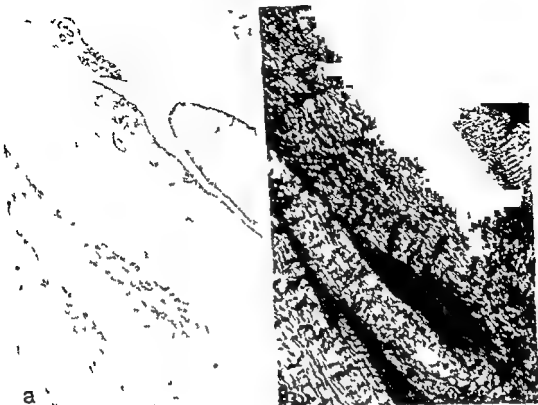


Figure 1 Case 1 Ligament bundles connected to fibrous tissue resulting from cicatricial remodelling

a) Normal light

b) Polarized light showing differences in structure between pre-existing ligament bundles (lower left) and fibrous scar tissue (upper right)—(Haematoxylin eosin $\times 22$)

nistically useful immediately after trauma because it is only later on that synovial hyperplasia develops, moreover misleading appearances can be produced by joint effusion. The rather discrete bone and cartilage changes observed in case 1 are not visible on X-rays but may be considered as early osteoarthritic changes similar to those sometimes seen in the subtalar joint (Brown 1960, Debrun 1963, Homprid 1966).

These pathological soft tissue changes in the sinus tarsi seem to be secondary mainly to rupture of the calcaneofibular ligament. This was observed clinically in nine cases in a previous study (Meyer & Taillard 1974). In our present case 1 the rupture was observed at operation and

was unassociated with any bone changes. Simple plasty of the ligament resulted in the disappearance of symptoms which were still absent after 6 months. This is consistent with Castaing's view on the role of the calcaneofibular ligament in subtalar stability (Castaing 1970).

An anatomical and radiological picture of the post traumatic sinus tarsi syndrome is thus recognizable. However it cannot be superimposed on a characteristic clinical picture. For example in case 1 which was radiologically and histologically typical there was rather diffuse pain in the mediotalar region and no elective pain over the sinus tarsi. Conversely a post traumatic syndrome featuring just such pain has been observed

in the absence of arthrographic changes
(Meyer & Taillard 1974)

ACKNOWLEDGEMENT

The authors express their thanks to Dr F Indermuhle (Porrentruy Hospital) for having kindly provided them with the clinical and radiological data for case 4

REFERENCES

- Brown, J E (1960) The sinus tarsi syndrome
Clin Orthop 18, 231-233
Castaing J (1970) Les entorses de la cheville
SOFOT Orthopédie et Traumatologie
Conférence d'Enseignement 1968, 23-41

- Debrunner, H U (1963) Das Sinus Tarsi Syndrom
Schweizer med Wschr 83 1660-1664
Hauser, F D W (1962) The sinus tarsi syndrome
Podologie 11-14
Komprda J (1966) Le syndrome du sinus du tarse
In *Ann Podologie* Vol 1 pp 11-14
Masson et Cie, Paris
Navarre, M (1966) A propos du syndrome du sinus du tarse
Acta orthop belg 32 743-747
Meyer, J M (1973) L'arthrographie de l'articulation sous astragalienne postérieure et de l'articulation de Chopart
These méd Genève No 3318
Meyer, J M & Taillard, W (1974) L'arthrographie de l'articulation sous astragalienne dans les syndromes douloureux post-traumatiques du tarse postérieur
Rev Chir Orthop 60, 321-330

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POSTOPERATIVE SYNOVIAL FLUID

Metabolic Response to Meniscectomy or Synovectomy

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The metabolic response of synovial tissue to surgery was investigated by synovial fluid analysis after two types of operations medial meniscectomy and synovectomy. Analyses of intra articular fluid were also performed in non-operated patients with traumatic effusion or chronic synovitis in the knee. It was found that the knee joint metabolism in chronic synovitis is shifted towards anaerobic glycolysis in both operated and non operated patients whereas meniscectomized and traumatized knees are more capable of maintaining oxidative metabolism. The data also demonstrate that one of the main reasons for decreased oxygen supply on the articular surface after meniscectomies or synovectomies is excessive intra articular effusion which, according to earlier investigations, produces pressure in the joint cavity and inhibits local capillary circulation.

Key words: synovial fluid analysis, synovial tissue metabolism, synovial gas tensions, meniscectomy, synovectomy, joint trauma, chronic synovitis, tissue repair.

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The useful information obtained from analysis of the synovial fluid has rendered this procedure an important factor in the diagnosis of joint disease. Under normal conditions the synovial tissue is highly vascular and it serves as a dialyzing membrane between the joint cavity and the circulation. Plasma dialysate flows into the joint cavity and serves to lubricate as well as to supply oxygen and other nutrients to the joint cartilage (cf Yehia & Duncan 1975).

Recent investigations have demonstrated that synovial fluid oxygen tension decreases to low levels in the knees of arthritis patients (Falcchuk et al 1970, Lund-Olesen 1970, Treuhart & McCarthy

1971, Goetzi et al 1974 a, b). In general, the lowest oxygen tensions have been found in inflammatory joint disease, followed in turn by degenerative and traumatic joint disease. These observations suggest the possibility that prolonged synovial fluid hypoxia might cause chondrocyte damage and death at the articular surface.

The low synovial fluid PO_2 in arthritic joints signifies a changeover of local tissue from predominantly aerobic to a largely anaerobic, glycolytic metabolism (McCarthy 1974). Ropes & Bauer (1963) observed an inverse relationship between synovial fluid glucose and lactate levels. Glucose diffuses into cells and is phos-

in the absence of arthrographic changes (Meyer & Taillard 1974)

ACKNOWLEDGEMENT

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REFERENCES

- Brown J F (1960) The sinus tarsi syndrome *Clin Orthop* 18 231-233
 Castaing J (1970) Les entorses de la cheville
 SOFCOT Orthopédie et Traumatologie
 Conférence d'Enseignement 1968 23-41

- Debrunner H U (1963) Das Sinus Tarsi Syndrom *Schweiz med Wschr* 93 1660-1664
 Hauser F D W (1962) The sinus tarsi syndrome *Podologie* 11 14
 Komprda J (1966) Le syndrome du sinus du tarse In *Ann Podologie* Vol I pp 11-15
 Masson et Cie Paris
 Navarre M (1966) A propos du syndrome du sinus du tarse *Acta orthop belg* 32 743-75
 Meyer J M (1973) L'arthrographie de l'articulation sous astragalienne postérieure et de l'articulation de Chopart Thèse méd Genève No 3318
 Meyer J M & Taillard W (1974) L'arthrographie de l'articulation sous astragalienne dans les syndromes douloureux post-traumatiques du tarse postérieur *Rev Chir Orthop* 60 321-330

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OXYGEN TENSION

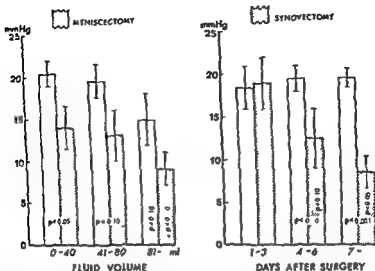


Figure 2 Oxygen tensions of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. In the first volume group the difference in PO_2 levels between meniscectomies and synovectomies was statistically significant ($P < 0.05$). In synovectomized patients $P < 0.05$ for the decline of PO_2 between the first and the third time group. In the third time group $P < 0.001$ for the difference of PO_2 between meniscectomies and synovectomies, $P < 0.10$ denotes almost significant.

CARBON DIOXIDE TENSION

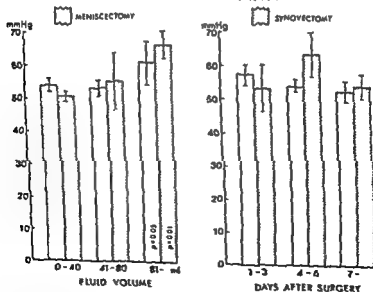


Figure 3 Carbon dioxide tensions of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. The statistically significant results are indicated as P-values (t test) in the corresponding columns.

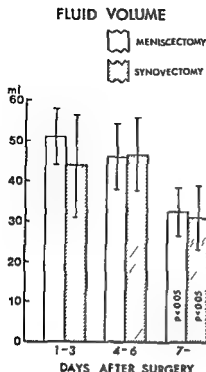


Figure 1 Volumes of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. Each column indicates the mean \pm the standard error of the mean. The decreases in fluid volumes between the first and the third time groups were statistically significant ($P < 0.05$ both for meniscectomies and synovectomies, t test).

phorylated which prevents it from diffusing out again until it is metabolized to pyruvate which in turn is converted to lactate.

Little is known about the metabolic response of synovial tissue to surgical trauma. In the present work this topic was investigated by means of postoperative synovial fluid analysis after two different types of operations, medial meniscectomy and synovectomy. For comparison, synovial fluid analyses were also performed in non operated hospitalized orthopedic patients with traumatic effusion or chronic synovitis in the knee joint.

PATIENTS AND METHODS

Postoperative synovial fluid analyses were carried out consecutively after 27 medial meniscectomies and 10 synovectomies.

The mean age of the meniscectomy patients was 39 years. Eighteen cases were caused by traumatic distortion and the preoperative period from the time of injury to the operation varied from 3 to 8 months. In nine patients the rupture was due to degeneration of the semilunar cartilage. The meniscectomies were carried out through a medial curvilinear or transverse incision and no postoperative tube drainage was employed. Mobilization of the knee was started on the first postoperative day, and weightbearing was initiated 10 to 14 days after surgery.

Indications for total synovectomy were rheumatoid arthritis (four patients), degenerative joint disease (three patients) and postoperative arthritis (three patients). The mean age of this group was 36 years. The synovectomies were performed through two separate parapatellar incisions medial and lateral followed by 2 days postoperative tube drainage. Mobilization of the knees was started on the first postoperative day and weightbearing was initiated 10 to 14 days after surgery.

Additionally, synovial fluid analyses were performed in five patients with traumatic effusion in the knee joint after a fresh injury (three intra articular fractures and two distal tibia fractures) and in nine non operated patients with chronic synovitis (six patients with rheumatoid arthritis, two patients with a degenerative joint disease and one postoperative arthritis).

The knees of the operated patients were inspected daily and if marked fluctuation was noted all accumulated fluid was aspirated with a sterile hypodermic needle into a heparinized glass syringe. The dead space of the syringe was filled with anoxic saline solution to prevent air bubbles from entering the sample. The volumes of the aspirated fluids were measured and the samples were placed on crushed ice and carried to the laboratory for the assay of PO_2 , PCO_2 and pH determination. Samples were injected into a thermostated cuvette containing either a Clark type oxygen electrode or a Severinghaus carbon dioxide electrode. The electrodes were connected with a gas monitor type PIM 71 (Radiometer Copenhagen Denmark). Zero adjustment of the O_2 electrode was obtained with gaseous nitrogen and calibration was performed at $37^\circ C$ using aerated saline solution with a PO_2 of 150 mmHg. The PCO_2 electrode was calibrated against two moistened gas mixtures with CO_2 tensions of 20 and 60 mmHg respectively. The pH of the fluid specimens was measured by means of a Radiometer pH meter attached to a Radiometer blood micro system type BMS 2 and the gas monitor.

Glucose in the synovial fluid was measured enzymatically with glucose oxidase (C.P. Boehringer et Soehne GmbH, Germany, Biochemical

OXYGEN TENSION

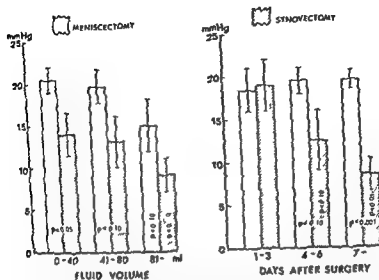


Figure 2 Oxygen tensions of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. In the first volume group the difference in PO_2 levels between meniscectomies and synovectomies was statistically significant ($P < 0.05$). In synovectomized patients, $P < 0.05$ for the decline of PO_2 between the first and the third time group. In the third time group, $P < 0.001$ for the difference of PO_2 between meniscectomies and synovectomies; $P < 0.10$ denotes almost significant.

CARBON DIOXIDE TENSION

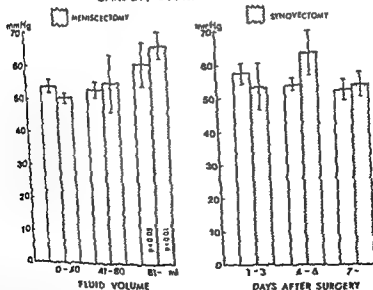


Figure 3 Carbon dioxide tensions of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. The statistically significant results are indicated as P -values (t test) in the corresponding columns.

pH

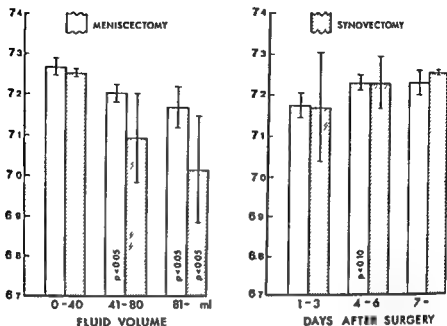


Figure 4 The pH of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy

GLUCOSE

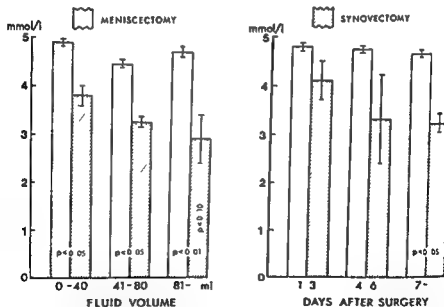


Figure 5 Glucose concentrations of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy

Test Combination) For determinations of synovial fluid pyruvate and lactate a 10 ml aliquot of fluid was deproteinized by adding an equal volume of ice cold 10 M perchloric acid. Pyruvate and lactate were determined by the standard

ultraviolet methods (C. P. Boehringer et Soehne GmbH Biochemical Test Combination) using a Beckman DU spectrophotometer. Hemoglobin was determined as cyanmethemoglobin as recommended by the European Society of Haematology

LACTATE

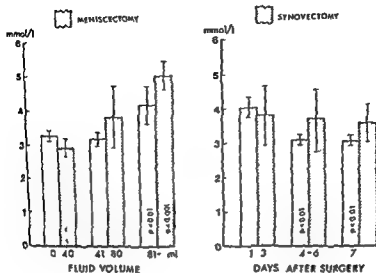


Figure 6 Lactate concentrations of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy

(1965) Protein was assayed with the Folin phenol agent as described by Lowry et al (1951) Bacteriological examination of synovial fluid samples showed that all joints remained uninfected throughout the study

The statistical significance of the results was calculated by means of Student's *t* test and linear regression analysis

RESULTS

During the postoperative period intra-articular accumulation of fluid declined gradually in both groups (Figure 1) Generally, the PO₂ levels after synovectomies were clearly lower than after meniscectomies (Figure 2) As healing progressed the PO₂ underwent a steep decline in the synovectomy group but remained unchanged after meniscectomies The PCO₂ values were relatively stable throughout the observation period (Figure 3) Both operated groups showed elevated carbon dioxide tensions in the largest fluid samples Overall, the mean pH increased slightly during the postoperative period and the lowest values

were observed in the largest postsynovectomy fluid samples (Figure 4) Glucose concentrations of the intra-articular fluid were significantly lower after synovectomies than after meniscectomies (Figure 5) The difference in glucose levels between the groups was maintained throughout the observation period Increases in fluid volumes were generally associated with elevations of lactate and the lactate/pyruvate ratio in both operated groups (Figures 6 and 7) In meniscectomies these parameters declined markedly during the early postoperative period In both operated groups accumulations of CO₂ and lactate were associated with a linear decrease of pH (for meniscectomies, see Figure 8) In meniscectomized joints the mean hemoglobin concentration decreased noticeably in large fluid volumes but showed no essential changes during the course of healing After synovectomies intra-articular hemoglobin underwent a slow decrease as tissue repair progressed Changes in hemoglobin concentration

LACTATE / PYRUVATE

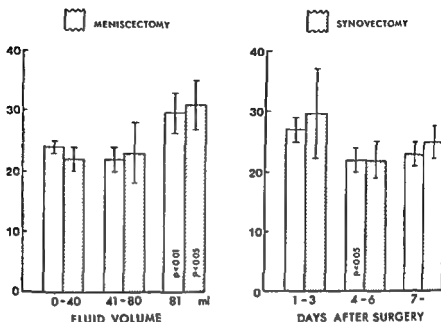


Figure 7 Lactate/pyruvate ratios of postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy

were reflected in corresponding changes in total protein in both operated groups (Figure 9)

In meniscectomized joints a high PO_2 level was associated with elevated levels of pH ($r = +0.65^{**}$) and hemoglobin ($r = +0.36^*$) and with decreased values of PCO_2 ($r = +0.74^{**}$) and lactate ($r = -0.40^*$). Synovial fluid PCO_2 was directly related to the concentration of lactate ($r = +0.50^{**}$) and the lactate/pyruvate ratio ($r = +0.43^{**}$). Inverse relationships were demonstrated between levels of lactate and pH ($r = -0.36^*$), and PCO_2 and pH ($r = -0.75^{**}$). Intra-articular hemoglobin concentration demonstrated a direct correlation with total protein ($r = 0.94^{**}$).

In synovectomized joints a low PO_2 value was associated with a decreased

glucose concentration ($r = +0.69^*$) and lactate/pyruvate ratio ($r = -0.63^*$). Both lactate concentration and lactate/pyruvate ratio were directly related to

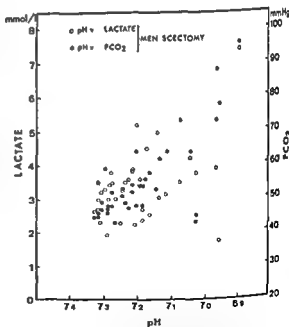


Figure 8 Relationship between postoperative synovial fluid PCO_2 or lactate and pH in knees of patients after medial meniscectomy

- * In linear regression analysis confidence limit for the correlation coefficient r was greater than 95 per cent
- ** in linear regression analysis confidence limit for the correlation coefficient r was greater than 99 per cent

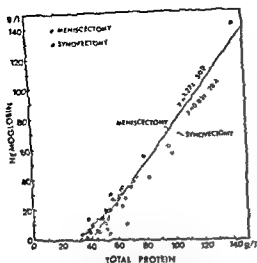


Figure 2 Relationship between hemoglobin and total protein concentrations in postoperative synovial fluids from knees of patients after medial meniscectomy or synovectomy. Linear regression equations are indicated.

carbon dioxide tension, with $r = +0.84^{**}$ and $+0.99^{**}$, respectively. Inverse relationships were found between lactate and pH ($r = -0.73^{*}$), and PCO_2 and pH ($r = -0.79^{*}$). Hemoglobin concentration correlated significantly with total protein concentration ($r = +0.93^{**}$).

In non-operated patients traumatic intra articular effusions possessed marked higher PO_2 levels, larger concentrations of hemoglobin as well as total protein and lower lactate/pyruvate ratios compared with synovial fluids from joints with chronic synovitis (Table 1). In non-operated chronic synovitis joints, synovial fluid PCO_2 was inversely related to the levels of PO_2 ($r = -0.66^{*}$) and pH ($r = -0.91^{*}$).

DISCUSSION

This report suggests that large intra articular accumulation of fluid reduces the availability of oxygen in the joint cavity (Figure 2). However, it is also possible that formation of fluid and tis-

sue edema are enhanced by local hypoxia. To test the relative importance of these two effects, the following experiment was performed. All fluid accumulated in the joints of four meniscectomy patients and three synovectomy patients was aspirated, fluid volumes were measured, and the analyses mentioned earlier were made. After 24 hours, aspirations and measurements were repeated. The latter samples were 30 to 50 per cent of the original volumes, and the mean PO_2 levels were nearly twice the original values.

Correspondingly, decrease in intra articular fluid volumes resulted in a decrease of both PCO_2 and the lactate/pyruvate ratio, whereas pH was elevated. These data demonstrate conclusively that one of the main reasons for decreased oxygen supply at the articular surface after meniscectomies or synovectomies is excessive intra articular effusion. On the other hand, the rate of accumulation of fluid is likely to depend on the extent of trauma produced during surgery.

An additional factor decreasing the PO_2 levels, especially after synovectomy, could be increased oxygen utilization by the large surface of healing tissue. This is supported by the fact that the intra articular PO_2 declined after synovectomies as healing progressed but remained nearly unchanged in meniscectomized patients. The overall high levels of intra articular PO_2 in both operated groups in the early postoperative phase were probably caused by capillary bleeding after a fresh trauma and also by diffusion of oxygen from the air during operation.

Intra articular accumulation of fluid probably produces excessive pressure in the joint cavity and this may inhibit capillary circulation and the supply of oxygen as well as other nutrients, to the repair area. Jayson & St John Dixon (1970) demonstrated that the intra articular pressure in the normal knee at

LACTATE / PYRUVATE

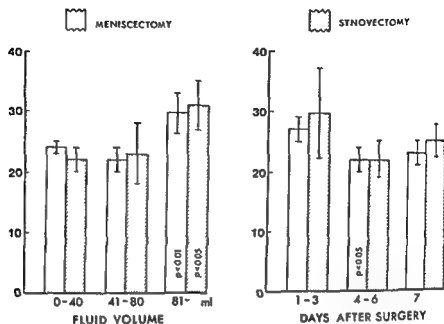


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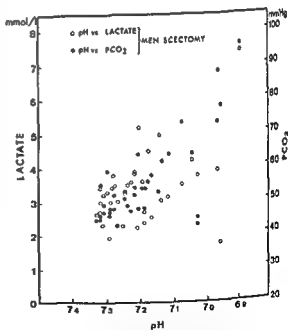


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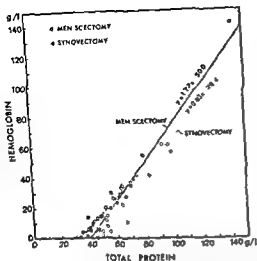


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DISCUSSION

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Table 1 Analysis of synovial fluid in non operated patients

	No of patients	Age of patients	Fluid volume (ml)	PO ₂ mmHg	PCO mmHg
Trauma *	8	42 ± 11	38 ± 5	28 ± 3	52 ± 4
Synovitis	9	37 ± 6	71 ± 14	12 ± 3	54 ± 3
P (t test)	—	NS	< 0.10	< 0.01	NS

* Duration from trauma to aspiration of fluid 1 to 3 days

Figures indicate the mean ± S.F.M

rest is approximately atmospheric, and with quadriceps contraction it becomes markedly negative. In the presence of effusion, this normal fall in intra-articular pressure is absent, or with larger volumes, reversed, so that a positive pressure results.

Postoperative PCO₂ values were elevated in samples with the largest fluid volumes (Figure 3), suggesting a decreased removal of CO₂ through the capillary bed. The major determinants of hydrogen ion concentration are PCO₂, the amount of lactate and buffering capacity. Therefore, as was expected, the accumulation of both CO₂ and lactate was associated with a decrease in pH (Figure 8). The lowest pH levels were observed in the largest fluid samples (Figure 4).

The low intra-articular glucose concentrations observed after synovectomies (Figure 5) could be due to impaired circulation at the surface of the joint cavity. Ropes & Bauer (1953) showed an inverse relationship between high intra-articular pressure and synovial fluid glucose concentration and suggested that glucose diffusion in the joint is impaired by blood vessel compression.

Results of studies of the concentrations of lactate (Figure 6) and the lactate/pyruvate ratios (Figure 7) showed that increase in the intra-articular fluid volume caused a shift of local metabolism towards anaerobic glycolysis. This change in cellular metabolism tends to increase the glucose consumption and

may, therefore, contribute to the decrease of synovial fluid glucose levels. After meniscectomies the levels of the lactate/pyruvate ratio underwent a marked decline during healing, suggesting a change over to more oxidative metabolism.

Obviously, some of the differences in various parameters between joints with small and large effusions could be due to qualitative alterations in the composition of intra-articular fluid causing variation in the osmotic pressure. Changes in the intra-articular hemoglobin concentration were reflected in corresponding changes in the total protein (Figure 9). Quite expectedly, the fluid hemoglobin levels underwent a gradual decline as post-operative bleeding ceased.

Synovial fluid analyses in non-operated patients indicated that in traumatic joints the intra-articular PO₂ was exceptionally high (28 mmHg), whereas the lactate/pyruvate ratio was lowest for the whole series (Table 1). On the other hand, in chronic synovitis joints the mean PO₂ was as low as 12 mmHg and the lactate/pyruvate ratio was elevated reaching the levels recorded in post-operative fluid samples. The protein content in traumatic effusions was high due to intra-articular bleeding. Synovial fluid glucose concentrations showed no variation between the non-operated groups.

The present work supports and extends the earlier findings suggesting that the very low oxygen tensions found in synovial fluid from joints with chronic synovitis are pathologic (Lund-Olesen

traumatic effusion or chronic synovitis in the knee joint

pH	Glucose mmol/l	Lactate mmol/l	Lactate/ pyruvate	Total protein g/l	Hemoglobin g/l
7.19 ± 0.06	4.60 ± 0.41	3.09 ± 0.65	198 ± 15	670 ± 155	363 ± 22.3
7.28 ± 0.04	4.40 ± 0.29	3.44 ± 0.23	238 ± 10	453 ± 32	0.17 ± 0.12
< 0.10	NS	NS	< 0.05	< 0.05	< 0.05

1970, Treuhart & McCarty 1971, Falchuk et al 1971) Widespread obliterative endangitis and very high metabolism of synovial tissue observed in rheumatoid arthritis may affect the oxygen supply of the joint and oxygen consumption (Laws et al 1963, Dingle & Page 1956) Direct measurements of *in vivo* oxygen consumption have shown that joints with rheumatoid arthritis utilize two to three times the oxygen of control joints (Goetzel et al 1974a) Obviously, the white cells present in the joints are not the major determinant of the steady state synovial fluid PO₂. This is supported by the study of Bodel & Hollingsworth (1966) who showed that the respiration of leukocytes in the synovial fluid of rheumatoid joints is less than 50 per cent of that of the leukocytes in peripheral blood

REFERENCES

- Bodel P T & Hollingsworth, J W (1966) Comparative study of oxygen consumption by synovial cells in vitro and in vivo. *J clin Invest* 45 580-589
- Dingle J T M & Page T D P (1956) In vitro studies on human synovial membrane a metabolic comparison of normal and rheumatoid tissue. *J clin Path* 9 353
- Falchuk, K. H., Goetzel, E J & Kulka, J P (1970) Respiratory gases of synovial fluids. An approach to synovial tissue circulatory-metabolic imbalance in rheumatoid arthritis. *Amer J Med* 49 223-231
- Goetzel, E J, Falchuk, K. H., Zieger, L. S., Sullivan, A. L., Hebert, C. L., Adams, J. P. & Decker, J. L. (1974a) A physiologic approach to the assessment of disease activity in rheumatoid arthritis. *J clin Invest* 50, 1167-1180
- Goetzel, E J, Nynes, R I & Stillman, J S (1974b) Abnormalities of respiratory gases in synovial fluid of patients with juvenile rheumatoid arthritis. *Arthr and Rheum* 17, 450-454
- Jayson M I V & St John Dixon, A (1970) Intra articular pressure in rheumatoid arthritis of the knee III Pressure changes during joint disease. *Ann Rheum Dis* 29 401-408
- Laws, J W., Lillie, J G & Scott, J T (1963) Arteriographic appearances in rheumatoid arthritis and other disorders. *Brit J Radiol* 36 477-493
- Lowry, O H, Rosebrough, N J., Farr, A L. & Randall, R J (1951) Protein measurement with the Folin phenol agent. *J biol Chem* 193 265-275
- Lund Olesen K (1970) Oxygen tension in synovial fluids. *Arthr and Rheum* 13 769-776
- McCarty, D (1974) Selected aspects of synovial membrane physiology. *Arthr and Rheum* 17 289-293
- Ropes, M W & Bauer, W (1953) *Synovial fluid changes in joint disease* p 71 Harvard University Press Boston
- Treuhart, P H & McCarty, D (1971) Synovial fluid pH, lactate, oxygen and carbon dioxide partial pressure in various joint diseases. *Arthr and Rheum* 14 475-484
- Yehia, S R & Duncan H (1975) Synovial fluid analysis. *Clin Orthop* 107 11-24

Table 1 Analysis of synovial fluid in non operated patients

	No of patients	Age of patients	Fluid volume (ml)	PO ₂ mmHg	PCO mmHg
Trauma *	5	42 ± 11	38 ± 5	28 ± 3	52 ± 4
Synovitis	9	37 ± 6	71 ± 14	12 ± 3	54 ± 3
P (t test)	—	NS	< 0.10	< 0.01	NS

* Duration from trauma to aspiration of fluid 1 to 3 days

Figures indicate the mean ± S.E.M.

rest is approximately atmospheric, and with quadriceps contraction it becomes markedly negative. In the presence of effusion, this normal fall in intra-articular pressure is absent, or with larger volumes, reversed, so that a positive pressure results.

Postoperative PCO₂ values were elevated in samples with the largest fluid volumes (Figure 3), suggesting a decreased removal of CO₂ through the capillary bed. The major determinants of hydrogen ion concentration are PCO₂, the amount of lactate and buffering capacity. Therefore, as was expected, the accumulation of both CO₂ and lactate was associated with a decrease in pH (Figure 8). The lowest pH levels were observed in the largest fluid samples (Figure 4).

The low intra-articular glucose concentrations observed after synovectomies (Figure 5) could be due to impaired circulation at the surface of the joint cavity. Ropes & Bruer (1953) showed an inverse relationship between high intra-articular pressure and synovial fluid glucose concentration and suggested that glucose diffusion in the joint is impaired by blood vessel compression.

Results of studies of the concentrations of lactate (Figure 6) and the lactate/pyruvate ratios (Figure 7) showed that increase in the intra-articular fluid volume caused a shift of local metabolism towards anaerobic glycolysis. This change in cellular metabolism tends to increase the glucose consumption and

may, therefore, contribute to the decrease of synovial fluid glucose levels. After meniscectomies the levels of the lactate/pyruvate ratio underwent a marked decline during healing, suggesting a change-over to more oxidative metabolism.

Obviously, some of the differences in various parameters between joints with small and large effusions could be due to qualitative alterations in the composition of intra-articular fluid causing variation in the osmotic pressure. Changes in the intra-articular hemoglobin concentration were reflected in corresponding changes in the total protein (Figure 9). Quite expectedly, the fluid hemoglobin levels underwent a gradual decline as post-operative bleeding ceased.

Synovial fluid analyses in non-operated patients indicated that in traumatic joints the intra-articular PO₂ was exceptionally high (28 mmHg), whereas the lactate/pyruvate ratio was lowest for the whole series (Table 1). On the other hand, in chronic synovitis joints the mean PO₂ was as low as 12 mmHg and the lactate/pyruvate ratio was elevated reaching the levels recorded in post-operative fluid samples. The protein content in traumatic effusions was high due to intra-articular bleeding. Synovial fluid glucose concentrations showed no variation between the non-operated groups.

The present work supports and extends the earlier findings suggesting that the very low oxygen tensions found in synovial fluid from joints with chronic synovitis are pathologic (Lund-Olesen

tric ulceration may result from administration of antiinflammatory drugs such as corticosteroids and salicylates

Confinement to bed can predispose the patient to urinary infection and urinary stone formation. The diagnosis and treatment of these changes and complications usually necessitates further X ray investigations

Chronic skeletal disease often affects young people and children. These patients are at an early age subjected to a great number of radiological investigations. The chronic nature of their disease, and the prospect of continuing treatment and X ray investigations of the same patient for many decades, makes knowledge of the accumulated radiation dose important. In addition to the

because of their chronic disease, their youth and the exceptionally high number of X ray examinations. Both patients have undergone repeated operations (Table 1)

METHODS

Absorbed dose estimation

Radiation absorbed doses in patients from X ray investigations are often reported. Apart from skin doses gonad and bone marrow doses are often mentioned. However, we have not been able to find any publications dealing with the subject of this article, i.e., the accumulated radiation doses to patients with chronic skeletal disease.

Two papers by Hashizume et al (1972 a, b) reporting gonad dose and mean bone marrow dose (local dose to bone marrow averaged over the whole active marrow) were made use of for our calculations. The estimated doses in these reports are based on phantom measurements and are given for one radiograph (or fluoroscopy procedure) in different types of examinations and for four different age groups. In this study, the ages of the patients at the time of the X ray investigations and the number of radiographs are known. Therefore, Hashizume's data are suitable for our calculations. Registered gonad doses to men in our hospital (Gustafsson 1976) are in reasonably good agreement with the data of Hashizume et al (1972 a, b).

Considering the number of radiographs kept and the age of the patient at the examinations we thus calculated the gonad dose and the mean bone marrow dose for each patient. The results are given in Tables 2 and 3.

The absorbed dose from fluoroscopy was estimated according to measurements in our hospital of the total absorbed energy (integral dose) to the patient from examinations of the gastrointestinal tract showing that doses from fluoroscopy and radiography are about equal (Gustafsson 197a).

RESULTS

Estimating that one out of six radiographs taken is discarded because of bad quality or because it did not contribute to the making of a diagnosis, the total absorbed doses will be

total growth by irradiation of the growth zones (International Commission on Radiological Protection 1969)

Table 1

Patient no 530202 ♀ R.A.	
Onset 1937 at the age of 4 years	
Operations	
Removal of kidney stone	1939
Adductor tenotomy	1962
Total hip replacement	1974
Osteotomy of tibia	1975
Patient no 531002 ♂ R.A.	
Onset 1960 at the age of 1½ years	
Operations	
Synovectomy both wrists and several finger joints	1967
Resynovectomy one wrist and several finger joints	1968
Adductor tenotomy	1971
Synovectomy both elbows	1971
Synovectomy of knee	1973

PATIENTS

This study comprises calculations based on published dose values of the total radiation dose absorbed by two young patients with juvenile rheumatoid arthritis. They were chosen

Patient number	Mean bone marrow dose (rad)	Gonad dose (rad)
530202	9.3	12.0
531002	5.8	11.3

TOTAL RADIATION DOSAGE FROM X-RAY EXAMINATIONS IN RHEUMATOID ARTHRITIS AND OTHER CHRONIC SKELETAL DISEASES

A Study of Two Cases

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Young patients with rheumatoid arthritis and other chronic diseases of the skeleton are increasingly being operated on with replacement of major joints. The great number of associated X-ray examinations performed on these patients has caused some anxiety amongst orthopaedic surgeons. Two patients with juvenile rheumatoid arthritis have been studied. An attempt was made to calculate the total radiation dose to bone marrow and gonads. For lack of recommendations for the maximum permissible radiation dose to patients the dose calculated has been compared with the maximum permissible dose of radiation workers, and with the dose limit for non occupational irradiation of individuals. The yearly absorbed dose in these two patients is much lower than the maximum permissible dose of radiation workers and only slightly higher than the dose limit for non occupational exposure of individuals.

Key words: bone diseases, chronic disease, radiation dosage, rheumatoid arthritis

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Many patients suffer from chronic skeletal disease with an uncertain prognosis as regards cure, although the disease may not greatly shorten the expected life span. Rheumatoid arthritis is a typical example of such a disease.

These patients often undergo repeated orthopaedic operations. Before being operated on, they are usually X-rayed several times in order to follow the pathological changes. Postoperative radiography is often necessary. After total hip or knee replacement, X-ray examinations must be done at intervals for a long

time, in order to detect complications such as infection, at an early stage. The intervals between X-ray examinations vary greatly from one hospital to another.

Some of these chronic diseases engaging the skeleton also cause pathological changes in organ systems other than the locomotor system. Examples of this are renal amyloidosis in rheumatoid arthritis and aortic insufficiency in ankylosing spondylitis.

There may also be adverse effects of the treatment of these diseases, e.g., glau-

about 32 per cent to the mean bone marrow dose, compared with 23 and 13 per cent, respectively, from hip and pelvis examinations. It is also evident that relatively few examinations of the gastrointestinal tract give a high percentage of the absorbed dose.

For patient 581002, stomach examinations make the dominating contribution, 35 per cent of the mean bone marrow dose. The high gonad dose figure in Table 3 for the knee and foot examinations could well be an overestimation, since no dose values were available for examinations of the knee joint.

We also estimated the highest locally absorbed dose in bone marrow. This was done in two ways: 1) by relating the mean bone marrow dose in Tables 2 and 3 to the distribution of active bone marrow in the body (according to Hashizume et al 1972 b), 2) by using exposure factors and radiation output values according to the International Commission on Radiological Protection (1970) and percentage depth dose factors according to Trout et al (1952). Method 2) gave a 25-50 per cent higher estimated absorbed dose than method 1).

In patient 530202, the lumbar spine received the highest dose about 25 rad and in patient 581002 a maximum absorbed dose of 15 rad was estimated for the lower part of the dorsal spine and upper part of the lumbar spine.

Averaged over the period studied, patient 530202 has received about 0.5 rad per year mean bone marrow dose and 0.7 rad per year gonad dose, from X-ray examinations. Patient 581002 has received about 0.6 rad per year to bone marrow as well as gonads.

young patients from their frequent X-ray examinations. When calculating radiation doses in patients we always have the genetic and carcinogenic effects in mind. To calculate an expected risk for these patients of radiation induced cancer we would need dose figures also for breasts, lungs, thyroid and other organs and these data are not yet available.

Another factor of importance in irradiating children is the potential effect on growth when the growth zones receive high doses. The most frequently examined joint in each patient has had 30 to 40 radiographs which should not result in more than 10 rad to the growth zones and probably much less. The minimum stunting dose to children has been estimated to be well above 100 rad (International Commission on Radiological Protection, 1969).

Radiation dose from postoperative X-ray investigations

Another point of interest is how much is added to the total radiation doses by the postoperative X-ray examinations. Assuming that a patient has both hip joints and both knee joints replaced and there is a postoperative follow up program with five X-ray examinations of each hip and five X-ray examinations of each knee, that would add about 0.5 rad to the mean bone marrow dose, about 1 rad to the female gonad dose and about 5 rad to the male gonad dose. The male gonad dose could be reduced considerably by using an appropriate gonad shield or by pulling the testes out of the radiation field.

Radiation dose comparison

ICRP has not made any recommendations for a maximum permissible radiation dose to patients from X-ray examinations. Instead it is stated that 'the level should be as low as is consistent

DISCUSSION

Radiological effects

The main reason for this study was to estimate the absorbed dose in these

Table 2 Estimated mean bone marrow dose and gonad dose to patient no 530202, ♀, from 1 roentgen examinations performed during the period November 1957–October 1975 (—) means less than 10 mrad

Examination	Number of examinations	Number of radiographs kept	Mean bone marrow dose (mrad)	Gonad dose (mrad)
Heart, lung	23	71	390	140
Cervical spine	8	50	430	—
Dorsal spine	5	19	700	—
Lumbar spine, lumbosacral joints	8	22	920	1460
Hip, pelvis	23	47	1040	2360
Knee, foot	18	74	220	220
Shoulder, arm, hand	10	40	250	—
Urinary tract	31	132	2480	4550
Stomach, abdomen, barium meal	7	36 + fluoros-copy	1140	1310
Others	5	17	150	—
Total	138	508 + fluoros copy	7720	10040

Table 3 Estimated mean bone marrow dose and gonad dose to patient no 531002, ♂, from 1 roentgen examinations performed during the period June 1965–May 1974 (—) means less than 10 mrad

Examination	Number of examinations	Number of radiographs kept	Mean bone marrow dose (mrad)	Gonad dose (mrad)
Heart, lung	22	51	290	40
Cervical spine	8	54	460	—
Dorsal spine	2	6	280	—
Lumbar spine	3	12	500	240
Hip pelvis	4	9	260	1170
Knee, foot	19	122	220	2130
Shoulder, arm, hand	25	121	820	—
Urinary tract	1	14	240	150
Stomach abdomen	5	36 + fluoros-copy	1660	650
Others	3	9	70	—
Total	92	433 + fluoros copy	4800	4380

These figures should only be regarded as rough estimates of the real absorbed doses. Recalculations were done from median values of gonad doses reviewed by United Nations Scientific Committee on the Effects of Atomic Radiation (1972) and from bone marrow dose estimations for the United Kingdom (Committee on Radiological Hazards to Patients 1966) and the Netherlands (Weber

1964). The greatest deviation found was a 70 per cent higher mean bone marrow dose calculated from the UK data for patient no 530202. This difference is partly explained by the fact that the UK data are not specified for children.

From Table 2, for patient 530202, it can be seen that examinations of the urinary tract contribute about 45 per cent to the estimated gonad dose and

PAIN INDUCED CHANGES IN THE KNEE JOINTS ADULT RABBITS

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Rapidly progressing joint disease can be produced in the rabbit by intra-articular injection of concentrated papain. With the use of radioactive thymidine it is possible to demonstrate that the cartilage cells recover their ability to divide by mitosis at the same time as degenerative changes appear in the cartilage. Clusters of chondrocytes arise by mitosis of chondrocytes and not by a floating together of cartilage cells.

Key words: papain, cartilage, experimental osteoarthritis, mitoses, autoradiography.

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Experimental osteoarthritis can be induced in various ways. In recent years degenerative joint changes have been induced by excision of part of the joints (H 1969, Thompson & Bassett 1970), by traumatization of the joint cartilage (Bennet et al 1932, Carlson 1957, Lehtimäki 1963, Campbell 1969 and Lemmon et al 1971), compression (Crehn & Hult 1960, 1964, Ginsberg et al 1970, Thompson & Bassett 1970) or immobilization of the joints (Evans et al 1960, Hall 1963, 1964) or by dislocation of the patella (Bennet & Bauer 1937). By making a joint unstable (Marshall & Thompson 1971, Telhag & Lindberg 1972), it is possible to produce joint changes resembling those seen in human osteoarthritis (according to Collins 1949) such as flaking, fibrillation and erosion of the articular cartilage.

Proteolytic enzymes release chondroitin sulphate from the protein-polysaccharide complex in the matrix. Papain is a proteolytic enzyme, and when given intravenously or intra-articularly in rabbits, it causes joint changes similar to those seen in human osteoarthritis (Murray 1964, Bentley 1971, Farkas et al 1974).

It has been shown that when degenerative changes develop in the joint cartilage in man and in the rabbit, the chondrocytes recover their ability to synthesize DNA, i.e., to divide (Hult et al 1972, Telhag 1972). It has hitherto not been possible to demonstrate with certainty the presence of mitotic figures in normal joint cartilage in adult human beings or animals (Mankin 1963, 1964, 1968, Hult et al 1972, Telhag 1972, 1973).

The purpose of this investigation was to find out whether chondrocytes recover their ability to divide after intra-articular injection of papain, and to elucidate

with obtaining the required diagnostic information" (International Commission on Radiological Protection, 1970)

The International Commission on Radiological Protection recommendations for exposure of individuals (International Commission on Radiological Protection, 1966) implies that the maximum permissible dose to radiation workers is 5 rad per year and that no individual should receive more than 0.5 rad per year non-occupationally. Excluded from these yearly doses are natural irradiation and irradiation of a person as a patient. These dose limits are set for planning purposes and at levels considered to result in acceptable risks for radiological effects.

The average yearly doses of 0.5–0.7 rad to gonads and bone marrow calculated for the two patients could also be compared with the mean absorbed dose from natural sources which is about 0.09 rad per year (United Nations Scientific Committee on the Effects of Atomic Radiation, 1972).

Follow-up X-ray investigations

When planning a follow-up program, for instance after total hip replacement, the frequency of the X-ray examinations must be determined. Various factors should be considered, not only the type of operation done and the complications that may arise but also the age of the patient and the total radiation dose. In a follow-up program for young patients it is especially important to minimize the absorbed dose from X-ray examinations. This is done by effective shielding of organs not being examined, by reducing the number of projections and by using the most sensitive X-ray recording system that gives the information required.

ACKNOWLEDGEMENTS

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REFERENCES

- Committee on Radiological Hazards to Patients (1966) Final report of the committee. Majesty's Stationery Office London.
- Gustafsson M (1976) Unpublished data.
- Gustafsson M (1975) Integral absorbed dose from X-ray examinations of the gastrointestinal tract 1960 and 1974. Paper presented at Third European Congress of the International Radiation Protection Association, Amsterdam.
- Hashizume, T., Kato, Y., Maruyama, T., & Imoto, Y. (1972a) Genetically significant dose from diagnostic medical X-ray investigation in Japan 1969. *Health Physics* 23, 827–843.
- Hashizume, T., Kato, Y., Maruyama, T., Imoto, Y., Shiragaki, A. & Nishimura (1972b) Population mean marrow dose from diagnostic medical X-ray investigations in Japan. *Health Physics* 23, 845–853.
- International Commission on Radiological Protection (1966) Publication 9 Recommendations of the International Commission on Radiological Protection. Pergamon Press, Oxford.
- International Commission on Radiological Protection (1969) Publication 14 Radiosensitivity and spatial distribution of dose. Pergamon Press, Oxford.
- International Commission on Radiological Protection (1970) Publication 16 Protection of the patient in X-ray diagnosis. Pergamon Press, Oxford.
- Trout, F. D., Kelley, J. P. & Cathers, G. A. (1964) The use of filters to control radiation exposure to the patient in diagnostic radiology. *Amer J Roentgenol* 67, 946–950.
- United Nations Scientific Committee of Effects of Atomic Radiation Report (1972) *Ionizing radiation levels and effects* Vol. I.
- Weber, J. (1964) Beenmergdosis tengevolgde röntgendiaagnostiek. Thesis, Leiden.

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It has been shown that when degeneration

occurs, the cells are unable to divide (Hulth et al 1972, Telhag 1972). It has hitherto not been possible to demonstrate with certainty the presence of mitotic figures in normal joint cartilage in adult human beings or animals (Mankin 1963, 1964, 1968, Hulth et al 1972, Telhag 1972, 1973).

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REFERENCES

- Committee on Radiological Hazards to Patients (1966) Final report of the committee Her Majesty's Stationery Office, London
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- Gustafsson, M (1975) Integral absorbed doses in X-ray examinations of the gastrointestinal tract 1960 and 1974. Paper presented at the Third European Congress of the International Radiation Protection Association Amsterdam
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- International Commission on Radiological Protection (1969) Publication 14 *Radiosensitivity and spatial distribution of dose* Pergamon Press Oxford
- International Commission on Radiological Protection (1970) Publication 16 *Protection of the patient in X-ray diagnosis* Pergamon Press, Oxford
- Irout I, D. Kelley J P & Cathey, G A (1932) The use of filters to control radiation exposure to the patient in diagnostic roentgenology *Amer J Roentgenol* 67 946–963
- United Nations Scientific Committee of Effect of Atomic Radiation Report (1972) *Ionizing radiation levels and effects* Vol I
- Weber J (1964) *Becomingdosis tengefolge* de röntgendiagnostik Thesis Leiden

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The purpose of this investigation was to find out whether chondrocytes recover their ability to divide after intra-articular injection of papain, and to elucidate

the histological development of papain-induced joint changes

MATERIAL AND METHODS

The material consisted of 16 full grown (grey Silver) rabbits with roentgenographically closed epiphyseal lines. They were caged under normal conditions and fed on normal diet. The animals weighed 2010–2960 g (mean 2468). They were divided into two groups. The first group (12 animals) received 0.2 ml concentrated, sterile papain in the right knee joint, and the left served as a control. They were killed two at a time, 2, 3, 5 days and 1, 2 and 4 weeks after the injection of papain. The second group (4 animals) received 0.2 ml of a 20 per cent solution of concentrated, sterile papain in the right knee joint, and the left served as a control. They were also killed two at a time, 2 and 4 weeks after the injection of papain. Four hours before sacrifice, 40 μ Ci 3 H-thymidine was injected intra-articularly into both knee joints of the animals studied for 1, 2 and 4 weeks. The animals studied for 2, 3 and 5 days received two doses of 3 H-thymidine, each consisting of 40 μ Ci, intra-articularly into both knee joints, 24 and 18 hours, respectively, before sacrifice.

The animals were killed with an overdose of Nembutal iv (Abbott). None of the joints showed any signs of infection. Both knee joints were dissected and fixed in 10 per cent formalin solution. The patella, tibia and femur were dissected free and treated separately. The tibia and the femur were divided into two halves in the frontal plane with a circular saw. The pieces were decalcified in 50 per cent formic acid and 20 per cent sodium citrate. They were embedded in paraffin and cut into sections 5–7 μ thick.

The sections were stained with haematoxylin-eosin, safranin O and according to van Gieson. Autoradiograms of routine histological sections were prepared from both knees according to the dipping method with Ilford K2 liquid emulsion. The autoradiograms were exposed for 3 weeks after which they were developed in Gervert X-ray developer G 230 and fixed in Gervert X-ray fixer G 350. The sections were stained through the emulsion with Mayer's haematoxylin. As a rule three autoradiograms from the tibia, femur and patella of both knee joints from each animal were examined.

RESULTS

The animals showed no signs of a generalized toxic reaction to the injection of

papain. In fact, the animals did not seem to spare the treated knee, and all of them survived the experimental period.

Histological examination

None of the left control knees showed any evidence of degeneration. In one of the animals, receiving concentrated papain, a little osteoblastic activity was seen at the margin. The sections stained with Safranin-O showed normal staining properties of the matrix except for three animals given concentrated papain and killed 2 weeks (1 rabbit) and 4 weeks (2 rabbits) later. In these animals the matrix had lost the staining properties seen in all the other animals.

Findings 2 days after injection of concentrated papain. At the margins there was slight proliferation of cells in and near the perichondrium and periosteum but there were no signs of osteoblastic activity or new bone formation. The articular cartilage showed signs of degradation in both the animals. In one knee joint almost all the cartilage was necrotic. The degradation was reflected in death of cells, mostly in the columnar and transitional layers, whereas the superficial layer was normal. Thus, the cell nuclei stained weakly or not at all, and it was often difficult to distinguish the cell membrane from the surrounding matrix. No clusters were seen. In one animal there was flaking and fibrillation of the surface.

Findings 3 days after injection of concentrated papain. At the margins and in the tissue adjacent to the cruciate ligaments, there was proliferation of cells and the beginnings of osteoblastic activity in both animals. The degradation of the articular cartilage seemed to be more pronounced than at 2 days after the papain injection, with flaking of the superficial layer and fibrillation. The death of the chondrocytes could be seen down to the tidemark. No clusters were seen.

Figure 1 One week after injection of concentrated papain. The articular cartilage is almost totally necrotic. Single clusters flaking and fibrillation.
Magnification $\times 72$



Findings 5 days after injection of concentrated papain. The proliferation of cells at the margins and adjacent to the cruciate ligaments and the osteoblastic activity, were still more pronounced. This was also true of the changes in the cartilage. Flaking of the superficial layer and fibrillation could be seen. Deeper down in the cartilage total necrosis was seen and only a few chondrocytes. Clusters were not seen.

Findings 1 week after injection of concentrated papain. At the margins and to some extent in the tissues adjacent to the attachments of the cruciate ligaments there was proliferation of cells in and near the perichondrium and periosteum. Furthermore most of the specimens showed ingrowth of capillaries with osteoblastic activity, sometimes with signs of new bone formation. The articular cartilage almost always exhibited signs of degradation in both knee joints from each animal. In one knee joint almost the entire cartilage was necrotic. Degradation was reflected in the death of cells mostly in the non calcified layers of cartilage and particularly so in the columnar layer. Thus the cell nuclei stained only weakly or not at all and it was often difficult to distinguish the cell membrane from the surrounding

matrix. In one of the two knees there were clusters of chondrocytes as well as flaking of the outer layer of the cartilage and fibrillation, sometimes down to the calcification line (Figure 1).

Findings 2 weeks after injection of concentrated papain. At the margins and at the attachments of the cruciate ligaments, granulation tissue had formed with abundant fibrous cells and vessels, and the osteoblastic activity with new bone formation was much more striking than that seen 1 week after the injection. In some of the specimens osteophytes had begun to form at the margins. The degradative changes had continued to progress. The articular cartilage showed severe changes often with total necrosis of the cartilage and only a few chondrocytes. Clusters were seen only in occasional sections, as were flaking and fibrillation.

Findings 2 weeks after injection of 20 per cent papain. At the margins and at attachments of the cruciate ligaments, granulation tissue had formed and abundant osteoblastic activity was seen with new bone formation and in some slides osteophytes had begun to form. The degradative changes of the cartilage were not as pronounced as when concentrated papain was injected. The changes were

Figure 2 Two weeks after injection of 20 per cent papain. The articular cartilage of the transitional and columnar layers is almost totally necrotic. Single clusters.
Magnification $\times 28$



mostly limited to the transitional and columnar layers (Figure 2), whereas they were not so pronounced in the superficial layer. On the other hand, flaking and fibrillation were seen, as were clusters.

Findings 4 weeks after injection of concentrated papain. Histologically, the formation of osteophytes at the margins as well as the subchondral osteoblastic activity were more prominent. Some specimens also showed new bone formation subchondrally, although no definite evidence of sclerosis was seen. The cartilage was often completely necrotic, far down in the columnar layer, in some areas down to the calcification line, and occasionally the calcified cartilage was changed. Flaking, fibrillation and clusters were rare. Living chondrocytes were sparse.

Findings 4 weeks after injection of 20 per cent papain. The proliferation of cells at the margins and at the attachments of the cruciate ligaments was still more pronounced than 2 weeks after the injection, as was also the osteoblastic activity. Subchondrally, new bone formation was seen, and at the margins formation of osteophytes had begun. The degradative changes of the cartilage were less than after the injection of concentrated papain. The articular cartilage was not totally necrotic but in some

places necrosis of the chondrocytes was seen. Big clusters as well as flaking and fibrillation were observed.

Autoradiographic evaluation

Specimens from 8 of the 16 control knees (left) showed fairly sparse thymidine labelled chondrocytes. All 8 belonging to group 1 (right knee joint injected with concentrated papain). In none of the control knees belonging to group 2 (20 per cent papain injected into the right knee joint) were any thymidine-labelled chondrocytes found.

In group 1 (concentrated papain) sparse labelled chondrocytes were found in the articular cartilage in two knees but there was only inconclusive evidence of this in the other four knees, when the animals were killed 2, 3 and 5 days after the injection. Seven days after the injection, one of the knee joints contained abundant labelled chondrocytes but the other contained fairly sparse labelled cells.

Fourteen days after the injection of concentrated and 20 per cent papain rather abundant labelled chondrocytes were found, especially in the latter group where the cell necrosis was not so pronounced. In the group injected with concentrated papain and killed 4 weeks later, only sparse labelled chondrocytes were found.

The labelled chondrocytes were usually situated in the superficial and transitional layers but also in the columnar layer. Clusters with labelled chondrocytes were also seen.

DISCUSSION

The availability of an experimental model is valuable in the investigation of the pathophysiology of osteoarthritis and the evaluation of therapeutic methods.

It has been shown (Bentley 1971, Farkas et al 1974) that degenerative and reparative changes resembling those in

concentrated papain caused rapidly progressing necrosis of the joint cartilage within 2 days, and after 4 weeks the non-calcified cartilage, and sometimes also the calcified layer, were so severely damaged that only occasional apparently viable chondrocytes were demonstrable. After the injection of 20 per cent papain, the changes in the articular cartilage were not so pronounced as when concentrated papain was injected, the changes being more of a degenerative nature. Like Bentley, we also found that chondrocytes in the deeper columnar layer were more affected than those in the superficial and transitional layers.

One week after the injection, the specimens showed abundant clusters of chondrocytes. With increasing time after the papain injection the number as well as the clusters of chondrocytes decreased, being less pronounced after injection of 20 per cent papain. Especially at 4 weeks after injection of 20 per cent papain, big clusters were seen. Collins & McElhagot (1960) found some evidence of proliferation of chondrocytes and clusters in osteoarthritis. Bentley (1971) described such clusters within 24 hours of an injection of papain into hip joints in the rabbit but we could not find any clusters

until 1 week after the injection. Bentley assumed that clusters were due to an aggregation of chondrocytes, secondary to loss of matrix. He felt that this could explain the development of clusters in osteoarthritis. Farkas et al (1974), on the other hand, found chondrocyte clusters with mitotic figures in the haematoxylin-eosin sections.

When degenerative changes of the articular cartilage are produced experimentally (Telhag & Lindberg 1972), mitosis of the chondrocytes is not seen until 5 days after the operation. Therefore, animals killed before 1 week were given 2 injections of titrated thymidine.

It has been shown that clusters can take up radioactive thymidine in degenerative joint disease both in the rabbit and in man (Hulth et al 1972, Telhag 1972). This was confirmed in the present investigation, in which it was shown that when degenerative changes of the cartilage occur the chondrocytes recover their ability to divide and, when situated in clusters, possess the ability to take up radioactive thymidine. This suggests that clusters arise from division, and not by 'a floating together' of cartilage cells. Thus, any type of damage of the joint cartilage stimulates the S phase of the mitotic cycle of the chondrocytes.

Mitosis of chondrocytes in the normal adult joint cartilage has hitherto not been demonstrated with certainty in animals or in man (Mankin 1963, 1964, 1968, Hulth et al 1972, Telhag 1972, 1973). When concentrated papain was given in the right knee, we found some labelled cartilage cells in the control knees, which might possibly have been due to a minute portion of the papain having been transported there. This perhaps also explains the negative safranin O staining in three of the control knees injected with concentrated papain. A technical fault can, however, not be excluded.

Bentley (1971) demonstrated formation of osteophytes resembling those seen

in human osteoarthritis after injection of papain. Such formation was verified in the present investigation. Four weeks after the injection of papain, the specimens exhibited incipient formation of osteophytes of the same appearance as those seen in human osteoarthritis according to Collins (1949), and in experimental osteoarthritis in the rabbit (Telhag & Lindberg 1972).

Many methods have been used for inducing osteoarthritic lesions in the joints. With papain, it is possible to produce advanced joint changes. In the present investigation, rapidly progressing changes in the articular cartilage were produced by the injection of concentrated papain. The changes produced in the articular cartilage seem to be of necrotic rather than of a degenerative nature. Papain, in lower concentrations, produces lesions more similar to those seen in human osteoarthritis thus also providing a possibility to study the earlier changes of degeneration and repair. Consequently, the method would appear to be useful for studying the metabolism of the joint cartilage in the early stages of joint disease.

REFERENCES

- Bennett, G. A., Bauer, W. & Maddock, M. J. (1932) A study of the repair of normal joints of adult dogs to surgically created defects of articular cartilage, "joint mice and patellar displacement." *Amer J Path* 8, 499-523.
- Bennett, G. A. & Bauer, W. (1937) Joint changes resulting from patellar displacement and their relation to degenerative joint disease. *J Bone Jt Surg* 19, 667-682.
- Bentley, G. (1971) Papain induced degenerative arthritis of the hip in rabbits. *J Bone Jt Surg* 53 B, 324-337.
- Campbell, C. J. (1969) The healing of cartilage defects. *Clin Orthop* 64, 45-63.
- Carlson, H. (1957) Reactions of rabbit patellar cartilage following operative defects. A morphological and autoradiographic study. *Acta orthop scand*, Suppl. 28.
- Collins, D. H. (1949) *The pathology of articular and spinal diseases*. Williams and Wilkins Co., Baltimore.
- Collins, D. H. & McElligott, T. F. (1969) Sulphate ($^{35}\text{SO}_4$) uptake by chondrocytes in relation to histological changes in osteoarthritic human articular cartilage. *Ann rheum Dis* 19, 318-329.
- Crelin, E. S. & Southwick, N. O. (1960) Mitosis of chondrocytes induced in the knee joint articular cartilage of adult rabbits. *Late J Biol Med* 33, 243-244.
- Crelin, E. S. & Southwick, W. D. (1964) Changes induced by sustained pressure in the knee joint articular cartilage of adult rabbits. *Anat Rec* 149, 113-133.
- Evans, E. B., Eggers, G. W. N., Butler, J. A. & Blumel, J. (1960) Experimental immobilization and remobilization of rat knee joints. *J Bone Jt Surg* 42 A, 737-758.
- Farkas, T., Bihari Varga, M. & Biró, T. (1974) Thermoanalytical and histological study of intra articular papain induced degradation and repair of rabbit cartilage I. Immature animals. *Ann rheum Dis* 33, 385-390.
- Ginsberg, J. M., Eyring, E. J. & Curtiss, P. H. J. (1969) Continuous compression of rabbit articular cartilage producing loss of hydroproline before loss of hexosamine. *J Bone Jt Surg* 51 A, 467-474.
- Hall, M. C. (1963) Cartilage changes after experimental immobilization of the knee joint of the young rat. *J Bone Jt Surg* 45-A, 36-44.
- Hall, M. C. (1964) Articular changes in the knee of the adult rat after prolonged immobilization in extension. *Clin Orthop* 34, 184-195.
- Hall, M. C. (1969) Cartilage changes after experimental relief of contact in the knee joint of the mature rat. *Clin Orthop* 64, 64-70.
- Hulth, A., Lindberg, L. & Telhag, H. (1972) Mitosis in human osteoarthritic cartilage. *Clin Orthop* 84, 197-199.
- Lempert, R., Boquist, L. & Rosenquist, J. (1971) Intracartilaginous defects in adult sheep. Histological, autoradiographical (^{35}S sulphate), ultrastructural, microradiographical and fluorescence studies. *Virchows Arch path Anat* 354, 1-16.
- Mankin, H. J. (1963) Localization of tritiated thymidine in articular cartilage of rabbits. III. Mature articular cartilage. *J Bone Jt Surg* 45 A, 529-540.
- Mankin, H. J. (1964) Mitosis in articular cartilage of immature rabbits. A histologic, stathmokinetic (colchicine) and autoradiographic study. *Clin Orthop* 54, 170-183.
- Mankin, H. J. (1968) The effect of aging on articular cartilage. *Bull NY Acad Med* 44, 545-552.
- Marshall, J. L. & Olsson, S. E. (1971) Instability of the knee. A long term experimental study in dogs. *J Bone Jt Surg* 53 A, 1561-1570.

- Leach m II (1963) The effect of scar f cation on articular cartilage in the rabbit *J Bone Jt Surg* 45 B 150-161
- Lurray D G (1964) Experimentally induced arthritis using intra articular papain *Arthr and Rheum* 7 211-219
- Telhag H & Lindberg L (1972) A method for inducing osteoarthritic changes in rabbits knees *Cl n Orthop* 214 223
- Telhag H (1972) Mitosis of chondrocytes in experimental osteoarthritis in rabbits *Cl n Orthop* 86 224-229
- Telhag H (1973) DNA synthesis in degenerated and normal joint cartilage in full grown rabbits *Acta orthop scand* 44 604-610
- Thompson H C J & Basset C A L (1970) Histological observations on experimentally induced degeneration of articular cartilage *J Bone Jt Surg* 52 A 435-443

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REFERENCES

- Bennett, G. A., Bauer, W. & Maddock, S. J. (1932) A study of the repair of normal joints of adult dogs to surgically created defects of articular cartilage, "joint mice" and patellar displacement. *Amer J Path* 8, 499-523.
- Bennett, G. A. & Bauer, W. (1937) Joint changes resulting from patellar displacement and their relation to degenerative joint disease. *J Bone Jt Surg* 19, 667-682.
- Bentley, G. (1971) Papain induced degenerative arthritis of the hip in rabbits. *J Bone Jt Surg* 53 B, 324-337.
- Campbell, C. J. (1969) The healing of cartilage defects in the rabbit patellary defects. A morphological and autoradiographic study. *Acta orthop scand*, Suppl. 28.
- Collins, D. H. (1949) *The pathology of articular and spinal diseases*. Williams and Wilkins Co., Baltimore.
- Collins, D. H. & McElhogg, T. F. (1969) Sulphate ($^{35}\text{SO}_4$) uptake by chondrocytes in relation to histological changes in osteoarthritic human articular cartilage. *Ann rheum Dis* 19, 318-329.
- Crelin, E. & Southwick, A. O. (1960) Mitosis of chondrocytes induced in the knee joint of articular cartilage of adult rabbits. *Yale J Biol Med* 33, 243-244.
- Crelin, E. & Southwick, W. O. (1964) Changes induced by sustained pressure in the knee joint articular cartilage of adult rabbits. *Anat Rec* 149, 113-133.
- Evans, E. B., Eggers, G. W. N., Butler, J. L. & Blumel, J. (1960) Experimental immobilization and remobilization of rat knee joints. *J Bone Jt Surg* 42 A, 737-758.
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- Hall, M. C. (1963) Cartilage changes after experimental immobilization of the knee joint of the young rat. *J Bone Jt Surg* 45 A, 36-44.
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- Hall, M. C. (1969) Cartilage changes after experimental relief of contact in the knee joint of the mature rat. *Clin Orthop* 64, 64-75.
- Hulth, A., Lindberg, L. & Telhag, H. (1972) Mitosis in human osteoarthritic cartilage. *Clin Orthop* 84, 197-199.
- Lempert, R., Boquist, L. & Rosenquist, J. (1971) Intracartilaginous defects in adult sheep. Histological, autoradiographical (^{35}S sulphate), ultrastructural, microradiographical and fluorochromic studies. *Virchows Arch path Anat* 354, 1-16.
- Mankin, H. J. (1963) Localization of tritiated thymidine in articular cartilage of rabbits. III. Mature articular cartilage. *J Bone Jt Surg* 45 A, 529-540.
- Mankin, H. J. (1964) Mitosis in articular cartilage of immature rabbits. A histological, stathmokinetic (colchicine) and autoradiographic study. *Clin Orthop* 34, 170-183.
- Mankin, H. J. (1968) The effect of aging on articular cartilage. *Bull NY Acad Med* 44, 545-552.
- Marshall, J. L. & Olsson, S. E. (1971) Instability of the knee. A long term experimental study in dogs. *J Bone Jt Surg* 53 A, 1561-1570.

- Meachim, G (1963) The effect of scarification on articular cartilage in the rabbit *J Bone Jt Surg* 45-B 150-161
- Murray, D ■ (1964) Experimentally induced arthritis using intra articular papain *Arthr and Rheum* 7 211-219
- Telhag, H & Lindberg, L. (1972) A method for inducing osteoarthritic changes in rabbits' knees *Clin Orthop* 86, 214-223
- Telhag, H (1972) Mitosis of chondrocytes in experimental "osteoarthritis" in rabbits *Clin Orthop* 86 224-229
- Telhag, H (1973) D\A synthesis in degenerated and normal joint cartilage in full grown rabbits *Acta orthop scand* 44, 604-610
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POROUS CERAMICS AS A BONE SUBSTITUTE IN THE MEDIAL CONDYLE OF THE TIBIA

An Experimental Study in Sheep Long-Term Observations

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A recent 3 month implantation study indicated that a new porous ceramic material might be suitable as a bone substitute in regions exposed mainly to compressive forces. The porous ceramics were implanted into the medial condyle of the tibia of sheep. In the present study the implants were left for 10 months in three animals, and 12 months in two. In the two animals with 12 months' observation, the plate which had been used to stabilize the implant was removed at 10 months. The implants and the adjacent bone tissue were studied macroscopically, radiographically and by microradiography and transmitted light microscopy. All the implants were bound to the adjacent bone by ingrowth of bony tissue. The depth of the bony invasion was slightly greater than that observed at 3 months, being maximally 3-4 mm. Some signs of ossification were still seen within the pores. The bony bridges between the implants and the surrounding bone were particularly well developed in regions of maximal stress. This was interpreted as a sign of active adaption of the bone formation to the actual stress to which the shearing surfaces were exposed. It is concluded that the properties of the porous ceramic implants justify a clinical trial in man.

Key words: bone substitute, porous ceramics, tibial condyle fracture

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In a previous study (Benum et al 1976) a new porous ceramic material was tested for possible use as a bone substitute in regions exposed mainly to compressive forces. The porous ceramics which mainly consisted of Al_2O_3 were implanted into the medial condyle of the tibia in sheep and left in position for 3 months. The implants were found to be bound to the adjacent bone by ingrowth of bony tissue. It was concluded that a clinical trial was justified if the results of long-term ob-

servations proved equally satisfactory.

In the present investigation we have studied the fate of the implants for up to 12 months and have paid particular attention to the anchorage of the implants to the surrounding bony tissue.

MATERIAL AND METHODS

The implants were similar to those used in the short term observations. The pore size was 100 μ (Benum et al 1976).



Figure 1 Radiographs of an implant 12 months postoperatively. The plate which was used to keep the implant in position was removed 2 months prior to sacrifice. A Frontal view. B Medial view. There is no sign of collapse of the tibial plateau and no sign of osteolysis around the implant.

Animals

Six female sheep, weighing 45–60 kg, were used. Their age varied from 5 to 8 years. Epiphyseal fusion of the tibia had occurred in all animals.

Surgical procedure, postoperative regimen

The operations were performed in exactly the same manner as described earlier; the postoperative regimen was also unchanged (Benum et al 1976). One animal died of intercurrent disease; the five others appeared totally unaffected by the operation.

Investigative procedure

Three animals were sacrificed 10 months after operation. In the remaining two the operated

knee was X-rayed at 10 months; the AO-finger-plate was then removed, and the animals allowed to resume their normal activities for another 2 months before they were sacrificed.

After sacrifice the operated knee and the proximal part of the tibia were removed and inspected; the specimens were fixed in formaldehyde, X-rayed and dehydrated in alcohol, and finally embedded in methylmethacrylate as described earlier (Benum et al 1976).

The subsequent investigative procedure was also similar, except that all sections were cut in the coronal plane.

Contact micro radiographs were taken of 300 μ thick sections, as described by Jowsey et al (1965). The sections were then ground down to a thickness of 40–50 μ and stained with Paragon

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1301 ("Paragon PS 1301", Paragon C & Co, 1 nc, Bronx, NY, USA)

Both contact micro radiographs and stained sections were examined by light microscopy

RESULTS

Function and macroscopic appearance

All the surviving animals recovered normal function after the operation. At sacrifice there were no signs of local infection or reaction around the implants. All the implants appeared firmly anchored to the surrounding bone, and there were no macroscopic signs of fracture of the implants or the tibial condyles.

Radiological examination

No signs of fracture or collapse of the implants or the tibial condyles were seen at sacrifice. There were no signs of resorption of bone above or below the implants. In the two cases where the plate had been removed 2 months prior to sacrifice, no radiographic changes were seen after removal of the plate (Figure 1).

Microradiography

The findings were almost identical in all the animals. In all parts of the implants which were in contact with bone, all surface irregularities and the most

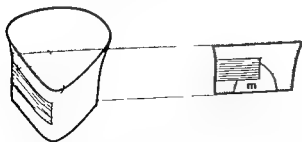


Figure 2 Schematic illustration of a specimen and a section removed from the middle part of the implant. The dotted area represents bony tissue *m* medullary cavity (The anterior and posterior regions and also the lateral part of the implant were surrounded by bone)

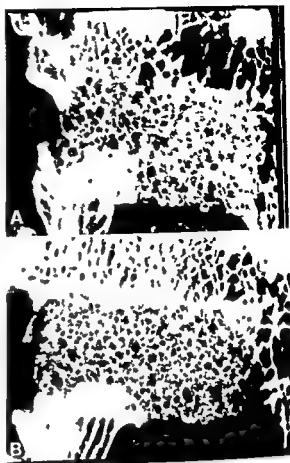


Figure 3 Microradiographs of sections through an implant. Observation period 10 months ($\times 25$). A From the transition zone between the anterior and middle third of the implant. B From the most posterior region. Ingrowth of bone is most extensive in the area corresponding to the supporting peripheral ring of bone. The maximal depth of bone invasion is approximately 4 mm (A). On the superior surface of the implant the bone invasion is also most pronounced medially. In both microradiographs the adjacent bone at the undersurface appears thickened.

peripheral pores appeared to be filled with bone. The invasion of bony tissue was most extensive in the part of the implants which rested upon the supporting peripheral ring of cortical or cancellous bone. The maximal depth to which the pores appeared to be filled with bone was 3–4 mm. The depth of bone invasion was considerably less in the superior surface of the implants. Here the ingrowth of bone appeared most pronounced along the periphery of the implants, in particular medially.

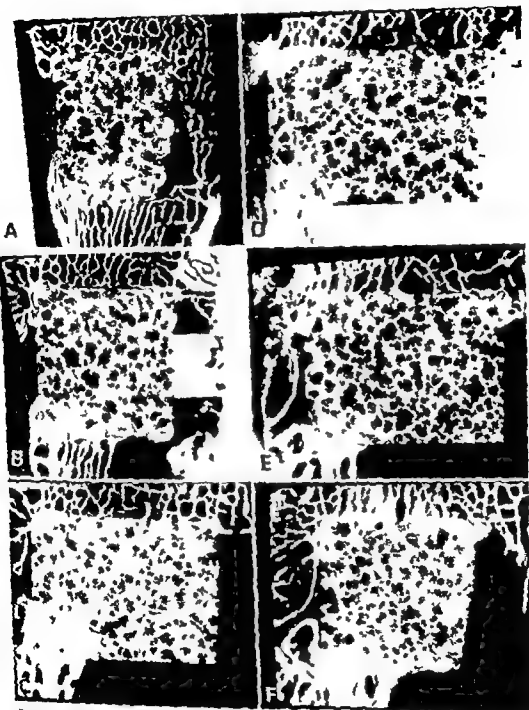


Figure 4 Microphotographs of sections of an implant (same implant as Figure 1) at 12 months (X 4). The microphotographs demonstrate the ingrowth of bone in the most anterior part (A) and further posteriorly to the most posterior part (F). The relation of bone ingrowth on to the adjacent bone is similar to that shown in Figure 3 but the extent of the ingrowth is slightly less pronounced. There is no ingrowth of bone in those parts of the implant which are not in contact with bone.

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Figure 3 Microradiographs of sections through an implant. Observation period 10 months ($\times 95$). A From the transition one between the anterior and middle third of the implant. B From the most posterior region. Ingrowth of bone is most extensive in the area corresponding to the supporting peripheral ring of bone. The maximal depth of bone invasion is approximately 4 mm (A). On the superior surface of the implant the bone invasion is also most pronounced medially. In both microradiographs the adjacent bone at the undersurface appears thickened.

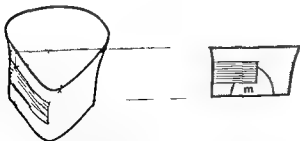


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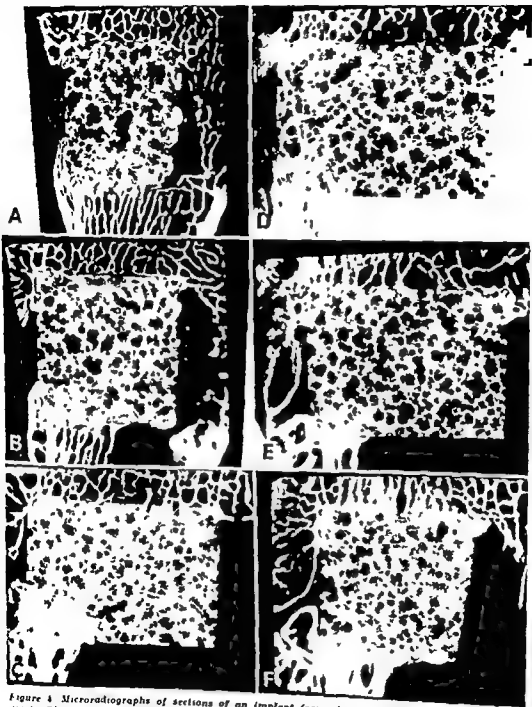


Figure 4. Microradiographs of sections of an implant (same implant as Figure 1) at 12 months ($\times 4$). The microradiographs demonstrate the ingrowth of bone in the most anterior part (A), and further posteriorly to the most posterior part (F). The relation of bone invasion to the adjacent bone is similar to that shown in Figure 3 but the extent of the invasion is slightly less pronounced. There is no ingrowth of bone in those parts of the implant which are not in contact with bone.

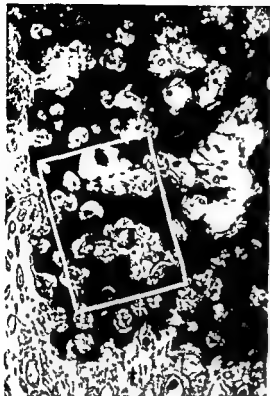


Figure 5 A General view from the lower part of the implant ($\times 115$). The picture demonstrates that the pores of the lower part of the implant are filled with bone. The pores of the more central region are filled with connective tissue (Compare Figure 5, B and C). The lower part of the implant is completely surrounded by bone. The bone trabeculae (t) of the adjacent bone are directly continuous with those of the bone within the pores (details in Figure 5 B).

Figure 5 Photomicrographs of a slide from the anterior part of an implant. The slide was prepared from the section demonstrated microradiographically in Figure 4 A (Paragon).

The adjacent bone was markedly thickened on the undersurface of the implants, corresponding to the area of maximal invasion. This was particularly true in the supporting peripheral ring of bone (Figures 3 and 4).

Histological examination

The histological examination verified the occurrence and distribution of bony tissue as found by the microradiographic investigation. The most peripheral pores were completely filled with bone in all areas of the implant surrounded by bony



Figure 5 B Detail from the lower part of Figure 5 A ($\times 28$).

tissue, and bony invasion in the deeper pores was found in the area adjacent to the peripheral ring of cortical or cancellous bone. Generally no connective tissue was seen interposed between the bony tissue and the ceramics in these regions. Most parts of the bony tissue appeared trabecular. The trabeculae of the adjacent bone were directly continuous with those of the new bone in the pores (Figure 5, A and B). Occasionally Haversian channels could be observed (Figure 5 D). In the central regions of the implants, and in those parts of the implants which were not adjacent to bone, the pores appeared to be filled with connective tissue (Figure 5 C). Occasionally narrow bone trabeculae surrounded by connective tissue were seen in these regions.

Osteoblasts and osteoid tissue were found on the surface of the bone trabeculae in some pores, indicating appositional bone growth (Figure 5 E). Intramembranous



Figure 5 C Detail from the area demarcated in Figure 5 A ($\times 28$) The occurrence of bone (b) within the lower pores and connective tissue (c) within the overlying pores (details in Figure 5 I) are demonstrated



Figure 5 D This picture demonstrates a Haversian channel (indicated by arrow) ($\times 115$)



Figure 5 E A row of osteoblasts (indicated by arrow) on the surface of the bone trabeculae (b) The dark zone between the osteoblasts and the bone represents osteoid tissue ($\times 115$)



Figure 5 F Demonstrating intramembranous ossification Osteoblasts (indicated by arrow) are seen at the border between the connective tissue (c) and the intramembranous bone (b) The dark zone lining the bone represents osteoid tissue ($\times 115$)

ossification was seen within some of the pores which contained connective tissue (Figure 5). Osteoclasts were rarely observed.

The connective tissue within the pores was generally well vascularized and contained fibroblasts (Figure 5, I and J). No special infiltration of round cells or

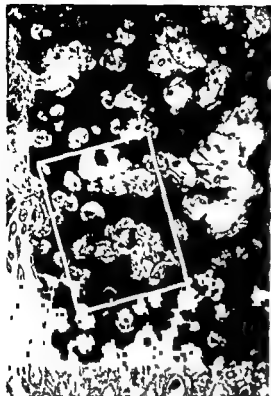


Figure 5 A General view from the lower part of the implant ($\times 115$). The picture demonstrates that the pores of the lower part of the implant are filled with bone. The pores of the more central region are filled with connective tissue (Compare Figure 5 B and C). The lower part of the implant is completely surrounded by bone. The bone trabeculae (t) of the adjacent bone are directly continuous with those of the bone within the pores (details in Figure 5 B).

Figure 5 Photomicrographs of a slide from the anterior part of an implant. The slide was prepared from the section demonstrated microradiographically in Figure 4 A (Paragon).

The adjacent bone was markedly thickened on the undersurface of the implants, corresponding to the area of maximal invasion. This was particularly true in the supporting peripheral ring of bone (Figures 3 and 4).

Histological examination

The histological examination verified the occurrence and distribution of bony tissue as found by the microradiographic investigation. The most peripheral pores were completely filled with bone in all areas of the implant surrounded by bony



Figure 5 B Detail from the lower part of Figure 5 A ($\times 23$).

tissue, and bony invasion in the deeper pores was found in the area adjacent to the peripheral ring of cortical or cancellous bone. Generally no connective tissue was seen interposed between the bony tissue and the ceramics in these regions. Most parts of the bony tissue appeared trabecular. The trabeculae of the adjacent bone were directly continuous with those of the new bone in the pores (Figure 5, A and B). Occasionally Haversian channels could be observed (Figure 5 D). In the central regions of the implants, and in those parts of the implants which were not adjacent to bone, the pores appeared to be filled with connective tissue (Figure 5 C). Occasionally narrow bone trabeculae surrounded by connective tissue were seen in these regions.

Osteoblasts and osteoid tissue were found on the surface of the bone trabeculae in some pores, indicating appositional bone growth (Figure 5 E). Intramembranous

was only slightly greater at 10 and 12 months compared with that at 3 months. However, the bone bridges between the host bone and the implants corresponding to the areas of high stress had developed considerably. It seems reasonable to assume that the bone formation within the pores during the earliest period after implantation represents a phase of unorganized callus formation. Remodelling then probably takes place due to the actual mechanical stress on the bone bridges between the bone and the implant. Such remodelling is of the utmost importance, not only if porous ceramics are to be used as a bone substitute, but even more so if this material should be employed in fixation of endoprostheses.

In the present experiments the connective tissue appeared highly active metabolically being vascular and rich in fibroblasts. Intramembranous bone formation was observed within this tissue and appositional trabecular bone formation was still taking place. It seems unlikely, however, that larger porous ceramic implants would become completely filled with bone, if applied clinically. Hence the strength of such implants can not be expected to increase significantly with the invasion of bone. According to the specifications of compressive strength given earlier (Benum et al 1976) it seems unlikely, however, that the porous ceramics should be weaker than the surrounding cancellous bone if used as a bone substitute in regions mainly exposed to compressive forces. The compressive strength of the porous ceramics employed in our studies compares favourably with the strength of cancellous bone in the tibial condyles reported by other investigators (Behrens et al 1974).

Porous alumina ceramics have previously been found to be chemically inert and it has further been shown that such ceramics do not produce any significant

adverse reactions after implantation (Klawitter et al 1969, Hulbert et al 1970, 1972, Rhinelander et al 1971, Nilles et al 1973). The findings of the present study, that osteocytes were lying close to the ceramics without interposition of connective tissue, and furthermore the lack of significant foreign body reactions around or within the implants, confirm that the ceramics possess a high degree of biocompatibility.

Due to the present knowledge of the properties of porous ceramics we feel that a clinical trial of porous ceramics as a bone substitute in regions mainly exposed to compressive forces is justified.

REFERENCES

- Behrens J C, Walker P E & Shoji H (1974) Variations in strength and structure of cancellous bone at the knee. *J Biomechan* 7 201-207.
- Benum P., Lyng S., Be O., Rafn I & Haffner J F W (1976) Porous ceramics as a bone substitute in the medial condyle of the tibia. *Acta orthop scand* 47 158-166.
- Hulbert S P., Morrison E J & Klawitter J J (1972) Tissue reaction to three ceramics of porous and non porous structures. *J Biomed Mater Res* 6 347-374.
- Hulbert S P., Young F A, Mathews R S, Klawitter J J., Talbert C. D & Stelling F H (1970) Potential of ceramic materials as permanently implantable skeletal prostheses. *J Biomed Mater Res* 4 433-456.
- Jowsey J., Phil D, Kelly F J., Riggs B L., Bianco A J, Scholtz M A & Gershan Cohen J (1965) Quantitative microradiographic studies of normal and osteoporotic bone. *J Bone Jt Surg* 47 A 780-806.
- Klawitter J J., Hulbert S F & Talbert C. D (1969) *Materials of construction for bone gap bridges*. Orthopaedic Surgery Papers of the Duke University Medical Center and Affiliated Hospitals USA.
- Nilles J L., Coletti J M Jr & Wilson C. (1973) Biomechanical evaluation of bone-porous material interfaces. *J Biomed Mater Res* 7 231-251.
- Rhinelander F W., Rouweyha M & Muner J C. (1971) Microvascular and histogenic responses to implantation of a porous ceramic into bone. *J Biomed Mater Res* 5 81-112.



Figure 5 G Detail from the contact area between bone and ceramics. A connective tissue is interposed between the bone (b) and the ceramics (ce). The osteocytes are lying close to the ceramics ($\times 360$)

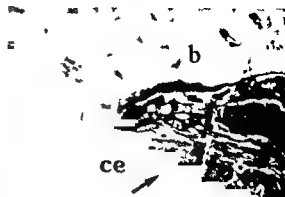


Figure 5 H Foreign body cells (indicated by arrow) lying between the bone (b) and the ceramics (ce). (The picture is overexposed in order to distinguish the cells from the dark surroundings) ($\times 360$)



Figure 5 I This picture shows highly vascular connective tissue within a pore ($\times 15$)

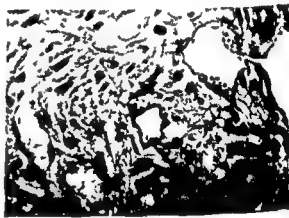


Figure 5 J Detail from Figure 5 I demonstrating that the connective tissue contains a considerable number of fibroblasts ($\times 360$)

leucocytes indicating inflammatory reaction could be observed within the implants. Osteocytes were observed close to the ceramics (Figure 5 G), in some regions, however, some foreign body cells could be observed (Figure 5 H).

There were no changes in the implants observed for 12 months which indicated loosening after removal of the plate.

DISCUSSION

We have previously reported that after 3 months porous ceramic implants were found to be bound to the adjacent bone by ingrowth of bony tissue, in some re-

gions to a depth of 2–3 mm. Some osteoid tissue and signs of osteoblastic activity were still seen (Benum et al 1976).

In the present study some ossification was still taking place within some pores of the implants. Since osteoclasts were rarely observed, it seems reasonable to assume that the appositional bone formation on the surface of the bone trabeculae leads to an increased bone mass, and not only reflects a process of remodelling. The finding of intramembranous ossification undoubtedly indicates that bony tissue is still being formed within pores previously occupied by connective tissue.

The maximal depth of bone invasion

was only slightly greater at 10 and 12 months compared with that at 3 months. However the bone bridges between the host bone and the implants corresponding to the areas of high stress had developed considerably. It seems reasonable to assume that the bone formation within the pores during the earliest period after implantation represents a phase of unorganized callus formation. Remodelling then probably takes place due to the actual mechanical stress on the bone bridges between the bone and the implant. Such remodelling is of the utmost importance not only if porous ceramics are to be used as a bone substitute but even more so if this material should be employed in fixation of endoprostheses.

In the present experiments the connective tissue appeared highly active metabolically being vascular and rich in fibroblasts. Intramembranous bone formation was observed within this tissue and appositional trabecular bone formation was still taking place. It seems unlikely however that larger porous ceramic implants would become completely filled with bone if applied clinically. Hence the strength of such implants can not be expected to increase significantly with the invasion of bone. According to the specifications of compressive strength given earlier (Benum et al 1976) it seems unlikely however that the porous ceramics should be weaker than the surrounding cancellous bone if used as a bone substitute in regions mainly exposed to compressive forces. The compressive strength of the porous ceramics employed in our studies compares favourably with the strength of cancellous bone in the tibial condyles reported by other investigators (Behrens et al 1974).

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REFERENCES

- Behrens J C, Walker P S & Shoji H (1974) Variations in strength and structure of cancellous bone at the knee. *J Biomechan* 7, 201-207.
- Benum P., Lyng S, Be O, Rahn I & Haffner J F W (1976) Porous ceramics as a bone substitute in the medial condyle of the tibia. *Acta orthop scand* 47, 158-166.
- Hulbert S F, Morrison S J & Klawitter J J (1972) Tissue reaction to three ceramics of porous and non porous structures. *J Biomed Mater Res* 6, 347-374.
- Hulbert S F., Young F A, Mathews R S, Klawitter J J., Talbert C. D & Stelling F H (1970) Potential of ceramic materials as permanently implantable skeletal prostheses. *J Biomed Mater Res* 4, 433-456.
- Jowsey J, Phil H, Kelly P J, Riggs B L., Bianco A J., Scholtz H A & Gershon Cohen J (1963) Quantitative microradiographic studies of normal and osteoporotic bone. *J Bone Jt Surg* 47A, 785-806.
- Klawitter J J, Hulbert S F & Talbert C. D (1969) *Materials of construction for bone gap bridges*. Orthopaedic Surgery Papers of the Duke University Medical Center and Affiliated Hospitals, USA.
- Villes J L, Coletti J M Jr & Wilson C (1973) Biomechanical evaluation of bone porous material interfaces. *J Biomed Mater Res* 7, 231-251.
- Rhinelander F W, Rowleyha M & Muner J C (1971) Microvascular and histogenic responses to implantation of a porous ceramic into bone. *J Biomed Mater Res* 5, 81-112.

PAIN RELIEVING EFFECT OF SCALENOTOMY

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A follow-up was made of 37 patients treated by section of the anterior scalenus muscle. They complained of pain and/or paraesthesia in the upper extremities and tenderness over the muscle. All experienced relief of pain after injection of a local anaesthetic into the anterior scalenus muscle. Twenty-five patients were markedly improved. Patients with neurological signs seem to have a better result than those without ($P = 0.06$).

Key words - scalenus anticus syndrome

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In patients with widely distributed pain or paraesthesia in the upper extremities the causal factor can be difficult to localize. A review is presented of 37 patients who were treated with scalenotomy, after an injection of local anaesthetic into the anterior scalenus muscle had given relief of pain or paraesthesia.

PATIENTS AND METHOD

All patients who underwent anterior scalenotomy from 1 April 1961 to 30 June 1976 have been reviewed. All had pain and/or paraesthesia in the upper extremity and tenderness over the anterior scalenus muscle except for three, who have been excluded.

The investigation includes 37 patients on whom 38 scalenotomies have been performed. The results of the operation were judged partly by the most recent notes in the case records—on an average 110 days (3-350 days) postoperatively—and partly from a questionnaire which was returned by 36 patients an average of 54 months (5-168 months) postoperatively.

RESULTS

Sex and age distributions in the patients are shown in Figure 1. Their symptoms,

signs and X-ray findings are included in Tables 1-3. Neurologic signs were found in 16 patients. Weakening of the hand shake was seen in eight patients, and one patient had weakened flexion/extension of the elbow joint. Several patients presented with atrophy, two had atrophy of the thenar muscles, one of the hypothenar muscles, one of the interosseous muscles and one of the upper arm. The results of the operation are shown in Tables 4 and 5. Because of the two maxima in the age distribution curve we divided the patients into two groups: one including patients younger than 30 years, the other one those older than 30. We analysed signs and efficacy of the operation in the two groups separately. Then they were compared according to the hypergeometric distribution (Therkelsen 1974). There was no difference in signs between the two groups. The result of the operation was statistically better in the younger group, comparing the statements in the case records ($P = 0.005$), but there was no difference if comparison was made of the questionnaires ($P > 0.15$). Patients with neuro-



Figure 1 Sex and age distribution

logic signs seem to be relieved more often than patients without ($P = 0.06$). There was no difference in the efficacy of the operation between patients with or with

out cervical rib. When present, it was never removed. The patients had had symptoms for an average of $2\frac{1}{2}$ years before the operation (1 month-15 years).

Table 1 Symptoms

Diffuse pain or paraesthesia	19
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Table 2 Physical signs

	Present	Not present	No information in the case record
Hypaesthesia	12	22	4
Paralysis	9	17	12
Muscle atrophy	5	27	6
Muscle atrophy	11	11	7

Table 3 X-ray changes

No abnormality	21
Cervical rib	8
Cervical spondylosis	3
Large transverse process of C VII	6

Table 4 The effect of scalenotomy as judged by the replies to the questionnaire

	Patients older than 30 years	Patients younger than 30 years	In all
No symptoms	4	1	5
Negligible symptoms	7	12	19
Unchanged symptoms	6	4	10
Aggravation	1	1	2

Table 5 The effect of scalenotomy as judged by the report in the case record

	Patients older than 30 years	Patients younger than 30 years	In all
No symptoms	3	3	6
Negligible symptoms	6	13	19
Unchanged symptoms	11	2	13
Aggravation	6	0	6

DISCUSSION

In patients with pain or paraesthesia in the upper extremity, with tenderness over the anterior scalenus muscle, the diagnosis of "scalenus (anticus) syndrome" was made when no other obvious cause, as for instance cervical disc syndrome, was found (Naffziger & Grant 1938, Judovich et al 1944, Shenkin & Somach 1963). However, Shenkin & Somach (1963) stated that the signs alone were insufficient for the diagnosis. At the Orthopaedic Hospital, in Aarhus, we agree with this and have used injection of a local anaesthetic (1 per cent Lidocaine) to relax the muscle and to see whether this would relieve the symptoms. In other clinics the physical examination has been supplemented by subclavian arteriography (Somerndike et al 1973) and ulnar nerve trunk conduction studies (Krogness 1973).

There are uncertainties in both methods of assessing the effect of scalenotomy. In the case records the follow-up varied. In the questionnaires, filled in many years after the operation, comparison with the preoperative state must be regarded as uncertain. The questionnaires show that the effect did not always last. The difference in efficacy of the operation, according to the two methods of arriving at the results, may be caused by a faster recovery in the younger patients.

Comparing our results of scalenotomy with other reports is difficult for three reasons: most investigations included relatively few patients, there is a varied incidence of cervical osteochondrosis and cervical rib, and different indications for scalenotomy have been used.

Rasmussen & Simonsen (1959) reported on 20 patients with "scalenus anticus syndrome", 70 per cent were re-

lieved, 80 per cent had cervical rib and 13 were younger than 30 years. Kallio & Rokkanen (1964) described 51 patients. Seventy-eight per cent were improved by scalenotomy, 47 were older than 30 and 90 per cent had cervical osteochondrosis. Shenkin & Somach (1963) conclude that patients with cervical rib and cervical osteochondrosis / abnormal myelogram are relieved more often than patients without these signs. We could not confirm this concerning cervical rib.

Conclusion

A comparison of our results with other reports does not seem to indicate that diagnostic injection of the muscle is a better criterion for selection for operation than a careful clinical examination.

REFERENCES

- Judovich, B, Bates, W & Drayton, Jr, W (1944) Pain in the shoulder and upper extremity due to scalenus anticus syndrome. *Amer J Surg* 63, 377-381.
- Kallio M & Rokkanen, P (1964) Effects of scalenotomy in the so-called scalenus anticus syndrome. *Acta orthop scand* 33, 59-66.
- Krogness, K (1973) Ulnar trunk conduction studies in the diagnosis of the thoracic outlet syndrome. *Acta chir scand* 139, 597-603.
- Naffziger, H C & Grant, W J (1938) Neuritis of the brachial plexus mechanical in origin. *Surg Gynec Obstet* 67, 722-730.
- Rasmussen, P & Simonsen, N (1959) Scalenus anticus syndromet. *Nord Med* 20, 1572-1573.
- Shenkin, H A & Somach, F A (1963) Scalenotomy in patients with and without cervical ribs. *Arch Surg (Chic)* 87, 892-896.
- Somerndike J M, Ostermiller, Jr, W E, Salyer J M & Camarata, S J (1973) Surgical management of thoracic outlet syndrome by first rib resection. *Amer Surg* 39, 250-252.
- Therkelsen A J (1974) *Medicinsk statistik* 3rd Edition p 28-30. Akademisk Forlag, København.

LATERAL DISLOCATION OF THE ELBOW

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A rare case of a pure lateral dislocation of the elbow joint is presented. Attempts at closed reduction were unsuccessful. At operation the anconeus muscle was found to be interposed between the articular surfaces of the joint preventing reduction.

Key words: elbow, lateral dislocation, anconeus muscle entrapment, operative treatment.

Accepted 6/77

Dislocation of the elbow joint is a very common injury, but a variant of this lesion, viz., the pure lateral dislocation of the elbow is extremely rare. Linseheid & Wheeler (1965), reviewing 110 cases of elbow dislocation at the Mayo Clinic over a period of 15 years, found only two cases of lateral dislocation. In Robert's report (1960) of 60 elbow dislocations there are only two cases of lateral dislocation. This specific type of elbow dislocation is also mentioned as being a very uncommon injury by other authors (Smith 1954, Rock & Green 1975).

The rarity of this lesion and the role played by the anconeus muscle in preventing closed reduction in our case justify this report.

CASE REPORT

A 33 year-old woman working on a farm fell from a mule onto her left arm and injured her elbow. She was admitted to the hospital a few hours later with a very painful swollen and deformed elbow joint. The forearm was fixed in pronation and there was a slight *varus deformity*.

Roentgenograms showed a lateral dislocation of the elbow without fracture of the joint

(Figure 1). Under general anaesthesia attempts at closed reduction were unsuccessful and therefore open reduction was performed.

The elbow joint was exposed using a posterior approach. The reduction of the dislocation was prevented by a tight band of the stretched anconeus muscle pressing against and folding the capsule into the dislocated joint. This fold of the capsule along with the tight band of the muscle over it was interposed between the lateral condyle and the trochlear notch obstructing the reduction (Figure 2). Reduction was achieved almost spontaneously when the anconeus muscle was dissected from its ulnar insertion.

The joint was immobilized in 90° flexion for 3 weeks in a plaster slab. After 6 months of physiotherapy a considerable range of elbow movement was regained with flexion/extension of 60 to 150° and full pronation/supination.

DISCUSSION

Pure lateral dislocation of the elbow is very rare (Rock & Green 1975). It is usually the most soft tissue damaging injury of all the varieties of elbow dislocation (Smith 1954) and therefore its closed reduction is an easy procedure.

However, difficulties in closed reduction can be encountered and are usually due to avulsion of the medial or lateral condyle of the humerus. This becomes in-

DISCUSSION

In patients with pain or paraesthesia in the upper extremity, with tenderness over the anterior scalenus muscle, the diagnosis of "scalenus (anticus) syndrome" was made when no other obvious cause, as for instance cervical disc syndrome, was found (Naffziger & Grant 1938, Judovich et al 1944, Shenkin & Somach 1963). However, Shenkin & Somach (1963) stated that the signs alone were insufficient for the diagnosis. At the Orthopaedic Hospital, in Aarhus, we agree with this and have used injection of a local anaesthetic (1 per cent Lidocaine) to relax the muscle and to see whether this would relieve the symptoms. In other clinics the physical examination has been supplemented by subclavian arteriography (Somerndike et al 1973) and ulnar nerve trunk conduction studies (Krogness 1973).

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Conclusion

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REFERENCES

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- Kallio, I & Rokkanen, M (1964) Effects of scalenotomy in the so called scalenus anticus syndrome. *Acta orthop scand* 33, 59-66.
- Krogness, K (1973) Ulnar trunk conduction studies in the diagnosis of the thoracic outlet syndrome. *Acta chir scand* 139, 597-603.
- Naffziger, H C & Grant, W J (1938) Neuritis of the brachial plexus: mechanical in origin. *Surg Gynec Obstet* 67, 722-730.
- Rasmussen, P & Simonsen, N (1959) Scalenus anticus syndrome. *Nord Med* 113, 1572-1573.
- Shenkin, H A & Somach, F A (1963) Scalenotomy in patients with and without cervical ribs. *Arch Surg (Chic)* 87, 892-896.
- Somerndike, J M, Ostermiller, Jr, W E, Salzer, J M & Camarata, S J (1973) Surgical management of thoracic outlet syndrome by first rib resection. *Amer Surg* 39, 250-252.
- Therkelsen, A J (1974) *Medicinsk statistik* 3rd Edition, p 28-30. Akademisk Forlag, København.

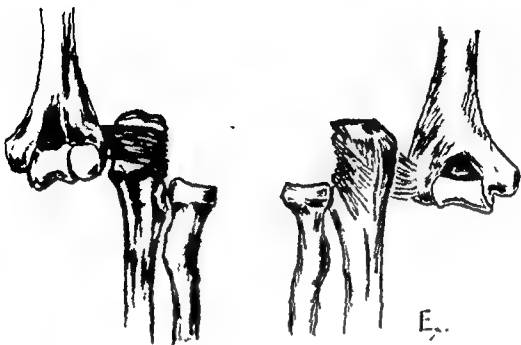


Figure 2 Schematic drawing of the lateral dislocation showing the undamaged anconeus muscle occupying the trochlear notch and obstructing the reduction

Rock A C. & Green P D (1975) *Fractures* Vol 1 p 521-527 Lippincott Philadelphia
 Smith M F (1954) *Surgery of the elbow* p 233-234 Charles C Thomas Springfield, Illinois
 Ujawa S (1966) Lateral dislocation of the elbow joint *Singapore med J* 7 139-141

Watson-Jones, R (1957) *Fractures and joint injuries* Vol 2 p 542-544 Livingstone, Edinburgh, London

Wilson J N (1960) The treatment of fractures of the medial epicondyle of the humerus *J Bone Jt Surg* 42 B, 778-781

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Figure 1 X ray showing the pure lateral dislocation of the elbow joint

serted in the elbow joint preventing the reduction. Such avulsed fractures very often accompany this type of injury especially in children (Watson Jones 1957, Wilson 1960, Vignya 1966).

Soft tissue interposition can also prevent closed reduction of this dislocation as in the case reported by Smith (1954). In his patient the brachialis muscle was found at operation to obstruct the closed reduction, although the capitellum was also avulsed in this particular case.

The anconeus muscle is another factor which can prevent reduction of this injury. Whenever this muscle remains intact it is stretched and may be displaced

into the trochlear notch, obstructing the reduction, as it is then interposed between the lateral humeral condyle and the ulna (Figure 2). This was found in our case and an almost automatic reduction was achieved after the extra-articular dissection of the anconeus muscle from its ulnar insertion.

REFERENCES

- Einscheld I. R. & Wheeler K. H. (1965) Elbow dislocations. *J Amer med Ass* 194 1171-1176.
 Roberts H. P. (1969) Dislocation of the elbow. *Brit J Surg* 56 806-815.

experienced symptoms of ulnar neuritis for periods varying from 14 days to 16 years. Fifteen of the patients had suffered for less than 6 months seven for 8 months to 1 year and twelve for more than 1 year. The neuritis in 20 patients was located on the dominant side of the body and on the non dominant side in 14 patients.

Arthritic changes in the elbow joint were detected in X ray photographs of five patients. Calcification just distal to the medial epicondyle of the humerus was found in one patient. Six patients suffered from acute elbow trauma three from pressure on the nerve during surgery under general anesthesia and in one patient the impairment began as a result of several days unconsciousness in hospital. An etiology stressed by Mumenthaler (1961) and Wadsworth & Williams (1973). Two patients had chronic elbow trauma and one had slight rheumatoid arthritis of the elbow joint. Seventy per cent of the patients had earned their living by hard manual labor. Patient complaints and objective findings can be seen in Tables 1 and 2.

Table 1 Arm symptoms of 33 patients (34 arms) preoperatively

Impaired work capacity	32
Paresthesia	33
Dispraxia	27
Reduced strength	18
Pain	9
Cold sensations	6

Table 2 Preoperative objective observations of the arms of 33 patients (34 arms)

Tenderness and paresthesia released from aponeurosis	32
Hypesthesia or dysesthesia	30
Atrophy of hand muscles	17
Paralysis of hand muscles	15
Claw posture	2

Operative procedure

The operation was performed as described by Osborne (1970). An incision exposed the ulnar nerve from the middle of the sulcus to about 6 cm distal to the sulcus. The overlying aponeurosis between the two heads of the flexor carpi ulnaris muscle was cut through completely. The procedure differed from Osborne's in so far as we judged it unnecessary to suture the sectioned up neurosis profound to the nerve. Only the subcutaneous and skin layers were sutured.

At surgery no morphological abnormalities were observed in or around the ulnar nerve in 18 patients. A structural change in the nerve (a flask shaped bulge) distally limited by the proximal border of the aponeurosis was found in 12 patients. Fibrous adhesions around the nerve in the sulcus were seen in four patients. No wound complications or clinical deterioration of nerve function were detected in any of the patients.

RESULTS

The follow up of 31 patients who had undergone 32 operations was carried out after a period of 7 months to 5 years. One of the original patients died and one could not be located but in both cases the first examination indicated pronounced improvement. The results of the 32 decompression operations appear in Tables 3 and 4.

Ninety per cent of the patients had recovered completely or were considerably improved in their work capacity. Sixteen patients reported complete freedom from symptoms of neuritis, thirteen patients obtained varying degrees of improvement and three patients complained of no improvement from the operation. During surgery, however, no ulnar compression was observed in these three patients, and the ulnar nerves appeared normal but all three suffered from additional neurological diseases, two from cervical disc collapse and one from massive post traumatic reflex dystrophy.

A second operation was required in two patients. One suffered symptom recurrence 6 weeks after primary surgery and during the second decompression operation a compressing fibrous coat was found surrounding the nerve in the cubital tunnel. The patient reported significant improvement 16 months later. In the second patient the secondary surgery was repositioning of the ulnar nerve, because only slight symptom relief resulted from decompression. However, during secondary surgery fibrous adhesions in

COMPRESSION NEURITIS OF THE ULNAR NERVE TREATED WITH SIMPLE DECOMPRESSION

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The purpose of this investigation was to test the hypothesis submitted by Osborne (1957), which proposed that the symptoms of compression ulnar neuritis, in most cases, result from compression on the ulnar nerve at the proximal border of the aponeurosis of the flexor carpi ulnaris muscle. Thirty-two simple decompression operations were performed on 31 patients, diagnosed as suffering from compression neuritis of the ulnar nerve. They were subsequently examined over a period of 5 years. Relief from symptoms was achieved in 28 cases, whilst four patients derived no improvement from the operation. Three of the four unsuccessful cases were judged to have been incorrectly diagnosed and were not suffering from compression of the ulnar nerve in the elbow. A second operation was required in two patients, in one a second decompression and in the other anteposition. No surgical or post-surgical complications occurred.

Key words: ulnar neuropathy, nerve decompression, compression neuritis, elbow, surgery, operative treatment, long term results

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Osborne in 1957 and Feindel & Stratford in 1958 proposed that the symptoms of ulnar neuritis, in most cases, result from compression of the nerve at the point where it descends below the aponeurosis which is stretched between the two heads of the flexor carpi ulnaris muscle, just distal to the sulcus nervi ulnaris. If this supposition is correct, Osborne pointed out that surgical treatment can be reduced to the simple procedure of cutting through the aponeurosis and widening the tunnel in which the ulnar nerve lies.

The objective of the work reported in this paper was to test the validity of the supposition and the surgical procedure proposed by Osborne.

MATERIAL AND METHODS

The investigation, begun in July 1970 and concluded in March 1975, was made on 33 patients, diagnosed as suffering from compression neuritis of the ulnar nerve. The patients were treated by simple decompression surgery at the Department of Orthopedic Surgery, Hjørring Hospital.

During this investigation period five additional patients with the same diagnosis were treated by anteposition of the ulnar nerve. Two of these patients suffered from pronounced rheumatoid-arthritis changes of the elbow joint: one from elbow arthritis with corpus liberum articulare and two from a thickened subluxating nerve. These five patients were not included in the results of the investigation.

Thirty-four decompression operations were carried out on 33 patients: one patient being operated on both sides. There were 25 men and 8 women, 18 to 73 years of age, with an average of 48 years. Prior to surgery the patients had

position Jensen (1959) based on an observation period of $1\frac{3}{4}$ years to 9 $\frac{1}{2}$ years reported that 30 out of 39 patients obtained relief from symptoms six gained slight improvement two were unchanged and one had aggravated symptoms

The results of decompression are also quite similar to those obtained from epicondylectomy *medialis humeri*. Based on a follow up period which ranged from 1 month to 1 $\frac{1}{2}$ years King & Morgan (1959) reported improvement in 18 out of 19 patients. Neblett & Ehn (1970) with an observation period of 1 month to 9 years obtained improvement in 13 out of 14 patients

Wadsworth & Williams (1973) employing a combination of anteposition and intra and extraneural lysis observed improvement in only 4 out of 12 patients after an observation time of 6 months to 1 $\frac{1}{2}$ years

Pechan & Julius (1975) proposed that the reason for the more or less similar results obtained from all of the above mentioned methods is due to the fact that the primary tension developing from elbow flexion is exerted from the flexor carpi ulnaris aponeurosis and in addition causes lengthening of the ulnar nerve each contributing about one-half of the directly measured increase in pressure on the ulnar nerve

Jensen (1959) and Zachariae (1967) proposed that the degree of surgical success in symptom alleviation is inversely proportional to the preoperative symptom duration in patients. This hypothesis was not supported by the results of the present investigation since 8 of the 11 patients who obtained the greatest improvement had preoperative ulnar neuropathy for more than 1 year one for 16 years and three for 8 years

In most cases diagnosis of compression neuritis of the ulnar nerve is not difficult

to make and only rarely is a case seen which is complicated and uncertain. Simple decompression is an operation which is so free of complications that it can be utilized with great latitude for example as a "diagnostic operation" in cases with uncertain diagnosis

The operation is most often successful when the site of maximal tenderness and paresthesia is located at the proximal border of the aponeurosis of the flexor carpi ulnaris muscle. Unquestionably, there are cases where anteposition is the most suitable operation particularly when there are pronounced changes in or around the elbow joint

REFERENCES

- Feindel W & Stratford J (1958) Cubital tunnel compression in tardy ulnar palsy. *Canad med Ass J* 78 331-333
- Jensen M (1959) Ulnar perineuritis. *Acta psych et scand* 34 205-221
- King T & Morgan F P (1959) Late results of removing the medial humeral epicondyle for traumatic ulnar neuritis. *J Bone Jt Surg* 41 B 51-55
- Mumenthaler M (1961) *Die Ulnarparese*. pp 203-219. Georg Thieme Verlag Stuttgart
- Neblett C & Ehn C (1970) Medial epicondylectomy for ulnar palsy. *J Neurosurg* 32 55-62
- Osborne G V (1947) The surgical treatment of tardy neuritis. *J Bone Jt Surg* 39 B 789
- Osborne G V (1970) Compression neuritis of the ulnar nerve at the elbow. *The Hand* 3 10-13
- Pechan J & Julius J (1975) The pressure measurement in the ulnar nerve. *J Biomech* 8 2-9
- Vanderpool D W, Chalmers J, Lamb D W & Whiston T E (1968) Peripheral compression lesions of the ulnar nerve. *J Bone Jt Surg* 50 B 799-803
- Wadsworth T C & Williams J H (1973) Cubital tunnel external compression syndrome. *Brit med J* 1 662-666
- Wilson D H & Kroul R (1973) Surgery of ulnar neuropathy at the elbow. *J Neurosurg* 38 780-785
- Zachariae J (1967) Anteposition ulnaris. *Ugeskr Læg* 33 1104-1107

Table 3 Postoperative improvement in symptoms in the arms of 31 patients (32 arms) related to preoperative complaints

	Preop	Complete recovery	Considerable improvement	Some improvement	No improvement
Impeded work capacity	31	23	5	1	2
Paresthesia	31	16	9	3	3
Dyspraxia	19	12	3	2	2
Reduced strength	16	5	6	1	4
Pain	9	6	0	2	1
Cold sensation	6	4	1	1	0

Table 4 Postoperative objective observations of the arms of 31 patients (32 arms) related to the preoperative condition

	Preop	Complete recovery	Considerable improvement	Some improvement	No improvement
Tenderness and paresthesia released from aponeurosis	31	25	4	2	0
Hypesthesia or dysesthesia	28	14	7	6	1
Atrophy of hand muscles	15	5	2	4	4
Paralysis of hand muscles	12	1	6	4	2
Claw posture	2	0	0	0	2

the sulcus nervi ulnaris were discovered. These had not been detected at the first operation. The patient reported complete recovery 2½ years later. These two patients were included in the results of the investigation, the first patient after and the second patient before the second operation.

DISCUSSION

Relief from symptoms by decompression surgery was obtained in 28 of the 32 cases, whilst four patients derived no improvement from the operation. In the author's judgment three of these four patients were incorrectly diagnosed, since the symptom picture was masked by other neurological difficulties. Decompression surgery for the fourth patient, as far as could be determined, was not performed in a standard manner and ante-position was subsequently performed.

The results of these operations correspond quite closely with other decompression investigations. Vanderpool et al (1968) reported that 32 out of 36 patients obtained relief from symptoms (observation time not recorded); however, the patients in that study were selected to exclude all long term cases of ulnar neuritis. Wilson & Krout (1973) with an observation period of 1 month to 2 years found improvement in 16 out of 16 patients (8 excellent, 4 good, 4 fair) with one patient who required secondary surgery for scar-tissue irritation. Feindel & Stratford (1958) reported improvement in three out of three patients with an observation time of 1 to 1½ years.

The results from decompression surgery closely resemble those from ante-position surgery. For example, Zacharine (1967), in a follow-up after 2 to 10 years reported that 41 out of 46 patients were improved, four were unchanged and one had aggravated symptoms following ante-

position Jensen (1959), based on an observation period of $1\frac{3}{4}$ years to 9½ years reported that 30 out of 39 patients obtained relief from symptoms six gained slight improvement two were unchanged and one had aggravated symptoms.

The results of decompression are also quite similar to those obtained from epicondylectomy medial humeri. Based on a follow up period which ranged from 1 month to 15 years King & Morgan (1959) reported improvement in 18 out of 19 patients. Neblett & Ehn (1970) with an observation period of 4 months to 9 years obtained improvement in 13 out of 14 patients.

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Jensen (1959) and Zachariae (1967) proposed that the degree of surgical success in symptom alleviation is inversely proportional to the preoperative symptom duration in patients. This hypothesis was not supported by the results of the present investigation since 8 of the 16 patients who obtained the greatest improvement had preoperative ulnar neuropathy for more than 1 year one for 16 years and three for 5 years.

In most cases diagnosis of compression neuritis of the ulnar nerve is not difficult

to make and only rarely in a case seen which is complicated and uncertain. Simple decompression is an operation which is so free of complications that it can be utilized with great latitude, for example as a diagnostic operation in cases with uncertain diagnosis.

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REFERENCES

- Feindel W & Stratford J (1958) Cubital tunnel compression in tardy ulnar palsy. *Canad med Ass* 78 351-353.
- Jensen F (1959) Ulnar per neuritis. *Acta psychiat scand* 34 207-221.
- King T & Morgan F P (1959) Late results of removing the medial humeral epicondyle for traumatic ulnar neuritis. *J Bone Jt Surg* 41 B 51-55.
- Mumenthaler W (1961) *Die Ulnarisparesen* pp 203-219. Georg Thieme Verlag Stuttgart.
- Neblett C & Ehn O (1970) Medial epicondylectomy for ulnar palsy. *J Neurosurg* 32 57-62.
- Osborne G A (1957) The surgical treatment of tardy neuritis. *J Bone Jt Surg* 39 B 782.
- Oslene C A (1970) Compression neuritis of the ulnar nerve at the elbow. *The Hand* 2 10-13.
- Pechan J & Julius J (1975) The pressure measurement in the ulnar nerve. *J Biomech* 8 75-79.
- Vanderpool D W, Chalmers J, Lamb H W & Whiston T B (1978) Peripheral compression lesions of the ulnar nerve. *J Bone Jt Surg* 50 B 797-807.
- Wadsworth T G & Williams J R (1973) Elbow tunnel external compression syndrome. *Brit med J* 1 662-666.
- Wilson D H & Krout H (1973) Surgery of ulnar neuropathy at the elbow. *J Neurosurg* 38 780-785.
- Zachariae I (1967) Anteposition in ulnaris. *Læskr fag* 35 1104-1106.

OPERATIVE TREATMENT OF ULNAR NERVE NEUROPATHY IN THE ELBOW REGION

A Clinical and Electrophysiological Study

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and Department of Clinical Neurophysiology, Karolinska Hospital, Stockholm, Sweden

Thirty-three patients with ulnar nerve neuropathy due to a lesion in the ulnar groove were operated upon during a 11 year period. All the patients were analyzed preoperatively. One-third of the patients had a history of alcohol abuse. Twenty-five of the patients were subjected to anterior transposition of the ulnar nerve. The results after transposition have been compiled according to etiology, duration, age and alcohol abuse. All seven patients with only subjective symptoms improved, 11 out of 11 (61 per cent) with motor and/or sensory loss also improved but only six (33 per cent) recovered completely. Overall, 21 patients (84 per cent) were improved by the operation. In 11 of the transposition cases the ulnar nerve was examined electrophysiologically before and after operation and an improvement of the motor conduction velocity within the elbow segment of the nerve was found in 10 cases.

Key words: ulnar nerve compression, elbow region, operative treatment, alcohol abuse, electroneurography

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The etiology and operative treatment of ulnar nerve neuropathies in the elbow region have been discussed in many papers since the first operation for this lesion was performed by Panas (1878).

The ulnar nerve can be subjected to a primary lesion due to direct trauma or damaged as a consequence of a fracture about the elbow region. Neural involvement may occur several years after a fracture due to valgus deformity of the elbow and stretching of the nerve during flexion.

The anatomical features around the ulnar nerve may be responsible for com-

pression neuropathy. When the ulnar nerve passes from the extensor aspect of the humerus into the forearm in the "cubital tunnel" (Feindel & Stratford 1958) it may be compressed between the fascial band bridging the two heads of the flexor carpi ulnaris and the capsular floor of the ulnar groove. The width of the tunnel is reduced in flexion of the elbow. Another factor causing narrowing of the cubital tunnel is synovitis with effusion (from osteoarthritis or rheumatoid arthritis) which protrudes into the groove. Rarely ganglia and soft tissue tumors may compress the nerve. In

some instances recurrent dislocation of the ulnar nerve may cause neuritis. Finally a group of patients remains in which none of these etiological factors are represented.

Three general categories of operative procedure have been used in the past:

- 1) Anterior transposition of the nerve subcutaneously (McGowan 1930, Goldware & Maxwell 1972) or buried in the flexor mass (Childress 1936, Levy & Apfelberg 1972)
- 2) Neurolysis i.e. breaking up of perineural adhesions (Osborne 1957, Feindel & Stratford 1958, Wilson & Krout 1973)
- 3) Epicondylectomy (Nicolle & Woolhouse 1963, King & Morgan 1970)

In this paper we present the etiology and clinical findings of 33 cases of ulnar groove syndrome treated over a 5 year period. Of these 25 were treated by anterior transposition of the ulnar nerve and were selected for a more intensive postoperative and recuperative study. The remaining eight patients received only freeing of the nerve.

MATERIAL AND METHODS

At the Orthopedic Clinic of St Goran's Hospital, Stockholm 33 patients underwent operation for ulnar groove syndrome during the period April 1969 to April 1974. The patients were referred to the orthopedic clinic from other clinics or from general practitioners. There were 11 women and 22 men and their ages varied from 9 to 69 years. The mean age was 44 years. Nineteen patients were "white-collar workers", housewives & retired persons. Eleven patients were laborers. Three were children.

All patients were operated on. In 25 cases anterior transposition of the nerve was performed while extra epineural decompression was carried out in the remaining eight cases. Twenty-seven patients were examined with X-ray prior to operation.

Etiology

As the etiology was obscure to us in many cases and as the majority of the cases in our

material cannot be classified as post traumatic we suggest a classification as shown below:

A Post trauma neuropathy 12		
Fracture in the elbow region	(11)	Primary neuropathy 8 Late onset of neuropathy 4
Dislocation of the elbow	(1)	
B Non traumatic neuropathy 21		
Postoperative	(1)	
Recurrent subluxation of the nerve	(2)	
Rheumatoid arthritis	(4)	
Idiopathic neuropathy	(14)	
Total 33		

A Post traumatic neuropathy In this group eight patients had sustained intra articular fractures with gross displacement and two patients had small fractures about the proximal part of the ulna. Two children with fractures of the shaft of the humerus had been treated with olecranon traction.

Eight patients who had the onset of their ulnar nerve symptoms at the same time as the accident are classified as primary. The late neuropathy group consisting of four patients had all sustained fractures in or about the elbow. They developed their symptoms 3 months, 2, 7 and 36 years after the accident.

B Non traumatic neuropathy In one patient the symptoms appeared after resection of an osteoid osteoma of the olecranon. Neuropathy in this case may have been due to prolonged stretching of the nerve in flexion during the immobilization.

In the idiopathic group no exogenous factor was found explaining the nerve damage and they are classified as idiopathic.

A history of alcohol abuse (alcohol consumption minimum 1 litre per week) was found in 11 patients. Eight patients could be referred to the idiopathic group, the remaining three belonged to the fracture group.

Duration of symptoms prior to operation

In the primary post traumatic neuropathy group the mean duration of symptoms was 11 months ranging from 1 day to 7 years. In the late post traumatic group the duration of nerve symptoms varied from 4 to 19 months.

In the non traumatic group the mean duration

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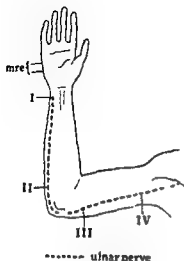


Figure 1 Ulnar nerve Position of stimulation and recording electrodes mre—muscle recording electrodes

IV III	627 ± 93
III II	371 ± 103 and
II I	561 ± 106 m/s

FNeG was done with stimulation of the mixed nerve at the positions I, II and III. Nerve action potentials were recorded at II (with stimulation at I) and at IV (with stimulation at II and III respectively). At the preoperative examination all patients except one had no visible nerve action potential for the distances I II and II IV. In one case a $15 \mu V$ potential with the conduction velocity of 49 m/s was recorded for the distance II IV. In all eight cases a nerve action potential was recorded for the distance III IV. Its mean value \pm standard deviation was $370 \pm 239 \mu V$, the conduction velocity was 629 ± 110 m/s.

EMG in the abductor digiti quinti muscle was recorded in nine cases. Partial denervation was found in five cases and in one case signs of a lesion of the peripheral motor neurons with reduction of voluntary activity but without signs of denervation was found. The other cases had normal EMGs.

Operative technique Transposition of the ulnar nerve

In a bloodless field tourniquet pressure $30-50$ mmHg above patient's systolic blood pressure and under general anesthesia the ulnar nerve was dissected free from the ulnar groove from the distal part of the upper arm and from the band joining the two heads of the flexor carpi ulnaris. This band was always split. Care was taken to respect the medial intermuscular

septum in the supracondylar region to avoid kinking of the nerve. After freeing the first branch to the flexor carpi ulnaris muscle the nerve was rerouted anterior to the medial epicondyle. Care was taken to secure a straight course for the nerve entering the flexor carpi ulnaris. In some instances the muscle had to be split but usually the nerve was located subcutaneously. The new course of the nerve was secured by a thin flap of adipose tissue loosely sutured medial to the nerve. After release of the tourniquet complete hemostasis was performed. A plaster slab was applied from the metacarpophalangeal joints to 10 cm above the elbow keeping the elbow immobilized for 10 days in 80° of flexion. After this period the plaster slab and stitches were removed and free movement was encouraged.

Operative findings

Local swelling of the nerve was found in two cases of idiopathic neuropathy in one case of rheumatoid arthritis and in two cases after a fracture (3 months or 56 years subsequent to the fracture). In three cases with symptoms occurring shortly after fracture which were promptly operated upon the ulnar nerves were edematous but there were no signs of pressure from bone fragments or any lesion of the nerve. No gross changes were seen in the remaining nerves.

Complications

There were two cases of hematoma that appeared on the first postoperative day. The patients were reoperated and in each case the bleeding vessel was ligated. In one of these two patients a partial ulnar nerve paralysis developed and persisted but the patient considered himself as improved.

CLINICAL RESULTS

All the patients were reexamined at hospital. The follow-up period ranged from 6 months to 4 years (mean 19 months).

The following factors were considered at the follow-up investigation:

- 1) Muscular wasting i.e. atrophy of the first dorsal interosseous muscle and/or paralysis of the adductor pollicis as demonstrated by Froment's sign.
- 2) Sensibility of the volar aspect of the little finger measured with the 2 PD test.

Table 1 Etiology and symptoms in the whole material (33 cases)

Etiology	No of cases	Subjective symptoms			Muscular wasting	Signs			Only subjective symptoms
		Numbness	Pain	Coldness		No	2 PD 7-15 mm	C mm	
FFL primary	8	7	3	2	5	5	2	0	1
EFL late	4	4	4	1	1	1	0	3	3
Postoperative	1	1	1	0	0	0	1	0	0
RIU	2	0	2	0	0	0	0	2	2
RA	4	4	4	1	0	1	2	1	1
Idiopathic	14	14	8	3	12	8	4	2	1
Total	33	30	22	7	18	15	9	8	5
Alcohol abuser	11	11	6	4	8	6	3	2	2

FFL = Fibrous fracture or luxation RIU = Recurrent luxation of the ulnar nerve

RA = Rheumatoid arthritis

of symptoms was 11 months ranging from 1 month to 24 months.

The alcohol abuse group presented a mean duration of symptoms of 17 months.

Clinical features

All the patients were right handed. The neuropathy was confined to the right arm in 18 of the 33 cases and in the idiopathic group in five cases out of 14.

Symptoms The dominant subjective symptoms were numbness and tingling in the little finger and the ulnar half of the ring finger and weakness of grip. These symptoms were present in all cases except three. Pain along the ulnar nerve in the forearm and hand was a dominant complaint in 22 cases. Seven patients had a sensation of coldness in the ulnar fingers. Eight patients had only subjective symptoms (Table 1).

Signs All patients demonstrated a positive Hoffmann-Tinel sign distal to the ulnar groove indicating the level of the nerve injury. At clinical examination 18 patients demonstrated atrophy of the first interosseous muscle and the same 18 patients had positive Froment's sign, i.e. pronounced flexion of the interphalangeal joint of the thumb when pinching with the index finger. No patient had motor impairment exclusively.

The sensibility was measured on the volar aspect of the fifth fingertip with the two point discrimination test (2 PD). Fifteen patients had complete loss of 2 PD, nine patients had impaired 2 PD (7-15 mm) and eight patients had normal or close to normal 2 PD (below 7 mm). In one patient sensibility could not be tested because of a previous finger amputation.

In the primary post-traumatic neuropathy group seven out of eight patients demonstrated signs of motor and/or sensory dysfunction. In the late post-traumatic group three patients out of four had only subjective symptoms. Among the 14 patients in the idiopathic group there was only one patient with solely subjective symptoms.

Electrophysiological examinations

Estimation of motor nerve conduction velocity (MCV) was performed on 13 of the patients of which 11 belonged to the transposition group (four from the post-traumatic and seven from the non-traumatic group). Only the results from these 11 patients will be discussed here.

Out of these 11 patients electroneurography (ENEG) was performed in eight cases. The MCV and ENEG examinations were done using the usual technique (Dawson & Scott 1949; Gilliatt & Sears 1958; Buchthal & Rosenfalck 1966; Wennerg & Widén 1966). Electrode positions I IV are shown in Figure 1. Electrical stimulation for the MCV estimation was always done with a unipolar needle electrode and the nerve action potentials were recorded with the same needle (an unisolated 0.3 mm tungsten electrode electrolytically polished to a tip diameter of 5-15 μ m inserted through the skin). To insert the needle as close as possible to the nerve a standardized procedure was used with the recording needle as stimulating cathode (Buchthal & Rosenfalck 1966). The preoperatively recorded MCV values of the 11 cases (mean \pm standard deviation) for the different inter-electrode distances (cf. Figure 1) were

Table 4 Improvement factor after transposition related to age ($n = 25$)

Symptoms/signs	No	Motor function improved	Sensitivity improved	Only subjective symptoms improved
< 50 years	12	4/5 (80 %)	5/7 (70 %)	5/5 (100 %)
> 50 years	13	2/7 (29 %)	6/11 (55 %)	2/3 (100 %)

Table 5 Improvement factor after transposition related to alcohol abuse ($n = 25$)

Symptoms/signs	No	Motor function improved	Sensitivity improved	Only subjective symptoms improved
Alcohol abuse	6	1/4 (25 %)	1/5 (20 %)	1/1 (100 %)
No alcohol abuse	19	5/8 (63 %)	10/13 (77 %)	6/6 (100 %)

postoperatively. Five patients with exclusively subjective symptoms all improved. Corresponding figures in the older group were motor improvement in two out of seven cases and sensory improvement in six out of eleven cases. Both patients with only subjective symptoms improved (Table 4).

B Severity and duration of symptoms

Eighteen patients had motor and/or sensory loss preoperatively. Only six patients with a duration of symptoms of 7 months, recovered completely. The other 12 improved only partially or not at all. The mean duration of symptoms in this group was 14 months. Seven patients with only subjective but typical symptoms all improved. The mean duration of symptoms in this group was 24 months.

C Alcohol abuse

Six patients with alcohol abuse were compared to the remaining 19 patients. Only one out of four patients with muscular wasting and one out of five with sensory loss improved in the former group (duration of symptoms 19 months). In the non-alcoholic group the corresponding figures were five out of eight for motor improvement and 10 out of 13 for sensory improvement (Table 5).

ELECTROPHYSIOLOGICAL RESULTS

Postoperative electrophysiological examination was performed between 6 months and 2 years after the operation except in one case, which was examined after 1 month. In all cases an increase of the MCV could be demonstrated for the distance III-II (cf. Figure 1), which is the elbow region of the nerve. The MCV mean value \pm standard deviation for this distance was postoperatively 47.7 ± 6.8 m/s, which is a highly significant ($P < 0.005$) increase from the preoperative value 37.1 ± 10.3 m/s. Postoperative MCV values for the other distances were IV-III 57.1 ± 4.1 and II-I 53.4 ± 8.2 m/s. These values are not significantly changed in comparison with the preoperative values. The postoperatively recorded nerve action potential was for the distance III-IV 37.8 ± 33.6 μ V with conduction velocity 63.6 ± 6.0 m/s which does not significantly differ from the preoperative values. In two cases it was possible to record nerve action potentials for the distances I-II and II-IV, where no measurable action potential could be recorded preoperatively. It was in both cases less than 20 μ V.

Thus, in this material MCV in the nerve segment III-II was the only electrophysiological variable that was signif-

Table 2 Results after transposition of the ulnar nerve (n = 25)

Symptoms/signs	No	Improved motor + sensory	Improved only sensory	Improved only subjective	Not improved
Motor and sensory loss	12	6 (4)*	1	2	3
Only sensory loss	6		4 (2)*	1	1
Only subjective	7			7	
Total	25	6 (4)*	5 (2)*	10	4

* In brackets, complete recovery

3) The patient's own evaluation with respect to pain, numbness tingling and weakness

Improvement of muscular function was defined as disappearance of Froment's sign and/or reappearance of palpable contractions of the first dorsal interosseous muscle. Improvement of sensibility was defined as improved 2 PD, e.g. change from no 2 PD to 15 mm or a measurable improvement exceeding 3 mm.

Out of 12 patients with combined motor and sensory loss, six patients improved in both respects, but only four patients recovered completely (two post-traumatic neuropathies operated on soon after fracture, one with rheumatoid arthritis with a duration of nerve symptoms of 70 days and one with idiopathic neuropathy for 12 months). In one patient only the sensibility improved. The remaining five improved only subjectively or not at all.

Four out of six patients with only sensory loss improved as measured with the 2 PD test: two of these regained normal 2 PD. The only patient made worse had normal motor function pre-operatively and demonstrated weakness of the first interosseous muscle at follow-up (post-hematoma).

Twenty-one patients (84 per cent) improved, three patients with objective symptoms improved only subjectively.

All seven patients with only subjective symptoms improved (Table 2).

The results divided according to etiology are given in Table 3.

Table 3 Results after transposition divided according to etiology (n = 25)

Etiology	Improved	Not improved
Posttraumatic primary palsy	6	1
Late palsy	3	1
Recurrent luxation of nerve	2	
Rheumatoid arthritis	4	
Postoperative	1	
Idiopathic	5	2
Total	21	4

PROGNOSIS OF ULNAR NERVE TRANSPOSITION

In an attempt to forecast the outcome of ulnar nerve transposition the importance of the patient's age, the severity and duration of the symptoms, and the influence of alcohol abuse were investigated.

A Patient's age

Twelve patients younger than 50 years were compared to 13 patients older than 50 years. In the younger group four out of five of the patients with motor loss and five out of seven with impaired sensibility improved.

athy may make the nerve more vulnerable

There seemed to be a difference between the younger age group and those patients older than 50 in favor of the younger group. However, the difference was not statistically significant. In agreement with Harrison & Varick (1970) we found that the duration of preoperative symptoms seemed to influence the outcome but only in cases with clinically evident motor and/or sensory loss. The prognosis in cases with only subjective symptoms was uniformly good in this material irrespective of the duration of the preoperative symptoms. This group may be compared to McGowan's grade I "Minimal lesions with no detectable motor weakness of the hand." Most reports of the results after transposition of the ulnar nerve have been enthusiastic. Thus, McGowan reports 75-100 per cent success even in cases of "tardy palsy" in a group consisting of 48 patients. Gay & Love (1947) found satisfactory results in 80 per cent of 100 patients but the majority were followed up by questionnaires and no data apart from the patients' opinions are given.

The results reported by Sunderland (1968) give another picture. Out of 14 patients only six improved (two patients were cured) and four patients were considered even worse after transposition.

In the present series 11 out of 18 patients (61 per cent) with motor and sensory loss improved but only six (33 per cent) recovered completely. The duration of symptoms of these six was half as long as in the group of 12 patients with partial or no recovery. Based on this series an early operation seems to give the best result.

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REFERENCES

- Broca, A. & Vouchet, A. (1899) Complications nerveuses des fractures de l'extrémité inférieure de l'humérus. *Rev. Chir. (Paris)* 19: 701-709.
- Buchthal, F. & Rosenfalck, A. (1966) Evoked action potentials and conduction velocity in human sensory nerves. *Brain Res.* 3 (Special Issue): 1-122.
- Childress, H. M. (1966) Recurrent ulnar nerve dislocation at the elbow. *J. Bone Jt. Surg.* 38 A: 978-984.
- Dawson, G. D. & Scott, J. W. (1949) The recording of nerve action potentials through skin in man. *J. Neurol. Neurosurg. Psychiat.* 12: 249-267.
- Downie, G. D. & Newell, D. J. (1961) Sensory nerve conduction in patients with diabetes mellitus and controls. *Neurology* 11: 876-882.
- Engkvist, O. (1972) Postoperative ulnar palsies (in Swedish). *Svenska Läk. Tidn.* 111: 3425-3431.
- Feindel, W. & Stratford, J. (1968) The role of the cubital tunnel in tardy ulnar palsy. *Canad. J. Surg.* 1: 287-301.
- Gay, J. R. & Love, J. G. (1947) Diagnosis and treatment of tardy paralysis of the ulnar nerve. *J. Bone Jt. Surg.* 29 A: 1087-1091.
- Gilliat, D. W. & Sears, T. A. (1958) Sensory nerve action potentials in patients with peripheral nerve lesions. *J. Neurol. Neurosurg. Psychiat.* 21: 103-118.
- Goldware, E. & Maxwell, J. A. (1972) Tardy ulnar palsy. *J. Kans. Med. Soc.* 73: 51-53.
- Harrison, M. J. G. & Varick, M. (1970) Results of anterior transposition of the ulnar nerve for ulnar neuritis. *Brit. med. J.* 1: 27-29.
- King, T. & Morgan, F. P. (1970) Late results of removing the medial humeral epicondyle for traumatic ulnar neuritis. *J. Bone Jt. Surg.* 101: 612-615.
- Knave, S., Holmström, H., Hedman, B., Persson, H. E. & Goldberg, M. (1974) Chronic exposure to carbon disulfide. Effects on occupationally

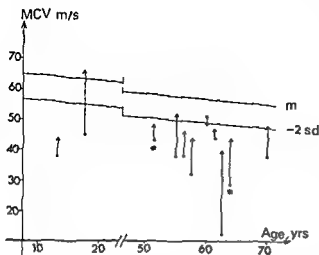


Figure 2 MCV in nerve section III-II (cf Figure 1). Every case is plotted as a vertical line, in which the dot marks the preoperative value and the arrow the postoperative value. The oblique lines denote mean values and -2 standard deviations in a material of healthy volunteers (from Knaus et al 1974). The two cases which were not improved clinically after the operation are marked with asterisks.

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The extent of electrophysiological improvement was not correlated to the age of the patient, the duration of symptoms, the genesis of the lesion, the severity of clinical symptoms or whether or not the patient had a history of alcohol abuse.

Postoperative EMG examination was performed in only six out of nine preoperatively examined cases. Two were slightly improved, the others were unchanged.

DISCUSSION

In classifying ulnar nerve neuropathies, in which the continuity of the nerve is not lost, one usually makes a division of the lesions into

- A Primary and secondary neuropathy resulting from trauma
- B Late neuropathy resulting from old fracture, arthritis, congenital anomalies, etc

In this material the group of late or tardy neuropathies consists of four cases—an astonishingly low figure in comparison with other consecutive series. These four patients had sustained fractures about the elbow 3 months, 2, 8 and 56 years prior to the neuropathy and only the patient with an interval of 56 years presented a cubitus valgus, thus fulfilling the criterion of the most common etiology of "tardy ulnar palsy" according to the classical observations of Broca & Mouchet (1899) and of Platt (1925).

Fourteen patients had no known previous injury to the elbow region. The etiology remains obscure to us in these cases and we could only find two cases of thickened nerve and no case of obvious compression of the nerve in this group.

A striking feature in this material not stressed in earlier reports, is the relatively large group, 11 cases (33 per cent), with a history of alcohol abuse. The results after transposition in this group are inferior to the results in the non-alcoholic group. It is probable that the ulnar nerve in alcohol abusers is more frequently subjected to small injuries or to compression and/or prolonged stretching with the elbow in flexion during sleep.

This pathogenesis has been suggested by Mumenthaler (1961), who accounts for 44 cases of ulnar neuropathy after states of prolonged unconsciousness and by Engkvist (1972), who found 12 ulnar palsies consequent to surgical operations under general anesthesia. Two of the alcohol abusers in this material also had diminished sensibility within the median nerve area in both hands, indicating polyneuritis, and it should be considered that even a subclinical alcohol neurop-

athy may make the nerve more vulnerable

There seemed to be a difference between the younger age group and those patients older than 50, in favor of the younger group. However, the difference is not statistically significant. In agreement with Harrison & Nurick (1970) we found that the duration of preoperative symptoms seemed to influence the outcome but only in cases with clinically evident motor and/or sensory loss. The prognosis in cases with only subjective symptoms was uniformly good in this material irrespective of the duration of the preoperative symptoms. This group may be compared to McGowan's grade 1 "Minimal lesions with no detectible motor weakness of the hand." Most reports of the results after transposition of the ulnar nerve have been enthusiastic. Thus McGowan reports 75-100 per cent success even in cases of "tardy palsy" in a group consisting of 46 patients. Gay & Love (1947) found satisfactory results in 80 per cent of 100 patients but the majority were followed up by questionnaire and no data apart from the patients' opinions are given.

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REFERENCES

- Broca, A. & Vouchet, A. (1899) Complications nerveuses des fractures de l'extremite inferieure de l'humerus. *Rev. Chir. (Paris)* 18: 701-709.
- Buchthal, F. & Rosenfalck, A. (1966) Evoked action potentials and conduction velocity in human sensory nerves. *Brain Res.* 3 (Suppl. Issue) 1-122.
- Childress, H. W. (1956) Recurrent ulnar nerve dislocation at the elbow. *J. Bone Jt. Surg.* 38 A: 978-984.
- Dawson, G. D. & Scott, J. W. (1949) The recording of nerve action potentials through skin in man. *J. Neurol. Neurosurg. Psychiat.* 12: 249-267.
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- Engkvist, O. (1972) Postoperative ulnar palsies (in Swedish). *Svenska Läk. Tidn.* 88: 3425-3431.
- Feindel, W. & Stratford, J. (1958) The role of the cubital tunnel in tardy ulnar palsy. *Canad. J. Surg.* 1: 287-301.
- Gay, J. R. & Love, J. G. (1947) Diagnosis and treatment of tardy paralysis of the ulnar nerve. *J. Bone Jt. Surg.* 29 A: 1087-1097.
- Gilliat, R. W. & Sears, T. A. (1958) Sensory nerve action potentials in patients with peripheral nerve lesions. *J. Neurol. Neurosurg. Psychiat.* 21: 109-118.
- Goldware, S. & Maxwell, J. A. (1972) Tardy ulnar palsy. *J. Kans. med. Soc.* 73: 51-53.
- Harrison, M. J. G. & Nurick, S. (1970) Results of anterior transposition of the ulnar nerve for ulnar neuritis. *Brit. med. J.* 1: 27-29.
- King, T. & Morgan, F. P. (1970) Late results of removing the medial humeral epicondyle for traumatic ulnar neuritis. *J. Bone Jt. Surg.* 52: 612-615.
- Knave, B., Holmström, H., Hedman, B., Persson, H. F. & Goldberg, M. (1974) Chronic exposure to carbondisulfide. Effects on occupationally

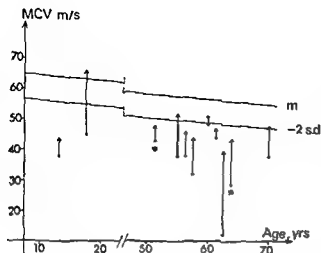


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REFERENCES

- Broca, A & Mouchet, A (1899) Complications nerveuses des fractures de l'extrémité inférieure de l'humérus. *Rev. Chir. (Paris)* 19: 701-709.
- Buchthal, F & Rosenfalck, A (1966) Evoked action potentials and conduction velocity in human sensory nerves. *Brain Res.* 3 (Special Issue) 1-122.
- Childress, H M (1956) Recurrent ulnar nerve dislocation at the elbow. *J. Bone Jt. Surg.* 38 A: 978-984.
- Dawson, G D & Scott, J W (1949) The recording of nerve action potentials through skin in man. *J. Neurol. Neurosurg. Psychiat.* 12: 249-267.
- Downie, G D & Newell, D J (1961) Sensory nerve conduction in patients with diabetes mellitus and controls. *Neurology* 11: 876-882.
- Engkvist, O (1972) Postoperative ulnar palsies (in Swedish). *Seenska 182-Tidn.* 88: 3425-3431.
- Feindel, W & Stratford, J (1958) The role of the cubital tunnel in tardy ulnar palsy. *Canad. J. Surg.* 1: 287-301.
- Gay, J R & Love, J O (1947) Diagnosis and treatment of tardy paralysis of the ulnar nerve. *J. Bone Jt. Surg.* 29 A: 1087-1097.
- Gilliat, R W & Sears, T A (1958) Sensory nerve action potentials in patients with peripheral nerve lesions. *J. Neurol. Neurosurg. Psychiat.* 21: 109-118.
- Goldware, S & Maxwell, J A (1972) Tardy ulnar palsy. *J. Kans. med. Soc.* 72: 51-53.
- Harrison, H J H & Nurick, S (1970) Results of anterior transposition of the ulnar nerve for ulnar neuritis. *Brit. med. J.* 1: 27-29.
- King, T & Morgan, F P (1970) Late results of removing the medial humeral epicondyle for traumatic ulnar neuritis. *J. Bone Jt. Surg.* 101: 612-615.
- Knave, B., Holmsten, H., Hedman, B., Persson, H. E. & Goldberg, M (1974) Chronic exposure to carbondisulfide. Effects on occupationally

- exposed workers with special reference to the nervous system *Wk Environ-Health* 11 49-58
- Levy, D M & Apfelberg, D B (1972) Results of anterior transposition for ulnar neuropathy at the elbow *Amer J Surg* 123, 304-308
- Lockner, D, Reizenstein, P, Wennberg, A & Widén, L (1966) Peripheral nerve function in pernicious anemia before and after treatment *Acta haemat (Basel)* 41, 257-263
- Lofstrom, B, Wennberg, A & Widén, L (1966) Late disturbances in nerve function after block with local anaesthetic agents *Acta anaesth scand* 10 111-122
- McGowan A J (1950) The results of transposition of the ulnar nerve for traumatic ulnar neuritis *J Bone Jt Surg* 32 B 293-301
- Mumenthaler, M (1961) *Die Ulnarisparese* p 406-409 Georg Thieme Verlag Stuttgart
- Nicolle, F V & Woolhouse, F M (1965) Nerve compression syndromes of the upper limb *J Trauma* 5 313-318
- Osborne, G V (1957) The surgical treatment of tardy ulnar neuritis *J Bone Jt Surg* 39 B 782
- Panas, J (1878) Sur une cause peu connue de paralysie du nerf cubital *Arch Gén Med* 2 5
- Pavan J (1970) Anterior transposition of the ulnar nerve An electrophysiological study *J Neurol Neurosurg Psychiat* 33 157-165
- Platt, H (1925) The pathogenesis and treatment of traumatic neuritis of the ulnar nerve in the postcondylar groove *Brit J Surg* 11 409-431
- Sunderland S (1968) *Nerves and nerve injuries* p 881-885 H D S Livingstone Ltd Edinburgh & London
- Wennberg A & Widén L (1966) Electrophysiological investigation methods in patients with injuries and functional disturbances in the peripheral nervous system (In Swedish) *Svenska Läk Tidn* 63, 3561-3571
- Wilson, D H & Kroust, R (1973) Surgery of ulnar neuropathy at the elbow 16 cases treated with decompression without transposition *J Neurosurg* 38 780-785

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PREVALENCE OF ADOLESCENT IDIOPATHIC SCOLIOSIS IN HUNGARY

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The prevalence of AIS was studied by examining 22,624 microfilms and obtaining additional clinical and radiological information in 201 out of 223 selected cases. In our material the total prevalence of scoliosis was 8.8-9.7 per thousand, whereas the prevalence of AIS was 1.5-4. Considering only AIS over 10° the prevalence was 2.91 per thousand.

Key words: idiopathic scoliosis, prevalence

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According to the age at onset, the sex, the type and location of the curve and the prognosis three groups of idiopathic scoliosis: (i) infantile, (ii) juvenile and (iii) adolescent can be distinguished (Beals 1973, James 1973, Mau 1972, Wynne-Davies 1968, 1975). Our study gives an account of the prevalence of adolescent idiopathic scoliosis (AIS) in Hungary.

MATERIALS AND METHODS

When surveying the prevalence of scoliosis at least five methodological aspects have to be taken into account:

1. *Definition of AIS* AIS can be defined as a visible more or less fixed, progressive curve of the spine accompanied by a rotation around the vertical axis of the vertebrae and a torsion in the horizontal plane occurring between the ages of 10 and 14 predominantly (90 per cent) on the right side and mostly in girls.

2. *Age* As AIS generally appears at 10-14 years of age only those over 14 years were examined.

3. *Definition of the sample* A series of fluorograms (microfilms) taken during routine X-ray screening were used. (i) The examinations were

obligatory, therefore, the requirement of completeness was fulfilled appropriately. (ii) The X-ray screening did not entail any selection for scoliosis. (iii) Microfilm seemed to be adequate for diagnosing scoliosis.

4. *Number of elements in the sample* Taking into consideration the prevalence of scoliosis reported in the literature 2-6 per thousand (Table 1), about 20,000 was set as the number of elements so that 2 SD falls below 20 per cent.

5. *Method of examination* After a screening based on microfilms, an exact diagnosis using full size radiography was made in each of the selected cases.

In 1974-75 22,624 microfilms from a definite geographical and administrative area (Dombóvár district) were examined. They had been taken in 1971 as part of the continual X-ray screening which has been carried out for those over the age of 14 in Hungary, since 1961. So not less than four, but in some cases 14 microfilms, could be examined in 11,450 females and 11,174 males. Comparing the microfilms of good quality showing the upper part of the lumbar spine we were able to eliminate several technical mistakes and in many cases to recognize the progress of scoliosis.

The examination was carried out in several stages. (i) The phthisiologist selected cases with the slightest signs of scoliosis or any other defects.

Table 1 The prevalence of adolescent idiopathic scoliosis

Authors	Year	Country	Definition	Age	Sample
Shands & Eisberg	1955	USA	AIS	14	representative
Lettow	1965	Democratic Republic of Germany	IS	0-18	representative
Wynne Davies	1968	Scotland	AIS	10-18	representative
Kane & Moe	1970	USA	AIS	14	hospital
Filho & Thompson	1971	Canada	AIS	?	hospital
Our material	1975	Hungary	AIS	14	representative

(ii) The microfilms of 413 selected cases were looked through by two orthopaedists independently (in order to eliminate subjectivity) and in 223 cases a distinctly visible curve was found on each microfilm.

(iii) These 223 scoliotic patients were requested to come for radiologic and genetic examinations during the spring of 1975. A total of 204 patients responded (91 per cent), 5 of them had died, and 14 did not appear even after repeated requests.

(iv) A detailed case history was obtained and a clinical examination made. A full size X-ray exposure of the spine in the standing position was taken for each of the 204 patients. The angle of curvature was determined according to Cobb's method (Neugebauer 1972).

RESULTS AND DISCUSSION

In three of the 204 patients who came for the examination, scoliosis was not found. Thus, based on 201 cases the total prevalence value for scoliosis, in the population of 22,624 individuals over 14 years of age, was 8.8 ± 0.6 per thousand. This figure includes all types of scoliosis. AIS occurred in 116 cases, so its prevalence is 5.1 ± 0.5 per thousand. The frequency of the so-called clinical cases (over 10°) was only 2.91 ± 0.35 per

thousand (66 cases). These values can only be considered as minimal prevalences since 19 patients were not examined. With only the microfilms available in these cases a diagnosis with a 98.7 per cent level of accuracy could be made, thus 8 of the 19 cases could be regarded as AIS, and 11 as other types of scoliosis. In this way the real prevalence of AIS is 5.4 ± 0.5 per thousand, whereas the total prevalence of scoliosis is 0.7 ± 0.6 per thousand.

It is important from the point of view of evaluating the prevalence values in our survey that curves between $5-10^\circ$ were also involved. In earlier definitions of occurrence, in nearly all cases only curves over 10° have been taken into account. We did not adhere to this for three reasons: (i) The milder cases are also needed for further genetic survey. (ii) The microfilm plus clinical and X-ray examinations formed a reliable basis for the diagnosis of mild as well as more severe cases. (iii) In judging the progression, knowledge of the initial angle is of great importance.

The prevalence of AIS in our country and in Europe, as well as in North

AIS) or idiopathic scoliosis (IS) in different countries

Number of sample	Method	Number of patients	Prevalence per 1000 persons	Sex ratio
15 000	microfilm + X ray in selected cases	61	4.0	0.2857
81,213	clinical examination	?	6.4	—
7,894	clinical examination + X ray in selected cases	17	2.2	0.1429
75,990	X ray	100	1.3	0.2000
?	X ray	413	1.8	0.1000
22 624	microfilm + clinical examination + X ray in selected cases	66 (above 10°) 116 (all cases)	2.9 5.1-5.4	0.2941 0.4762

Table 2 Type of scoliosis and severity of the curve in 201 scoliotic patients (f=females m=males)

	5-10° f m	11-20° f m	21-30° f m	31-50° f m	51-75° f m	over 76° f m	Total f m	Grand total %	Per cent
Idiopathic	28 22	24 7	8 3	13 3	2 2	4 0	79 37	116	57.6
Congenital	2 6	8 12	1 2	—	—	1 4	12 24	36	17.6
Sprengel	1 1	5 —	—	—	—	—	6 1	7	3.5
Scheuermann	5 3	— 3	1 —	—	—	—	6 6	12	6.0
Osteoporosis	3 2	2 3	—	—	—	—	5 5	10	5.0
Rickets	— 1	— 1	1 —	—	—	2 —	3 1	4	2.0
Staticeal	3 5	1 1	—	—	—	—	4 6	10	5.0
Polioomyelitis	—	—	1 —	—	—	1 —	1 1	2	1.0
Recklinghausen	1 —	—	—	—	—	—	1 —	1	0.5
Bechterew	— 1	— —	—	—	—	—	1 —	1	0.5
Cerebral palsy	— —	— 1	—	—	—	—	— 1	1	0.5
Spondylitis tuberculosis	—	—	1 —	—	—	—	1 —	1	0.5
Total	43 41	40 27	12 6	13 3	2 2	8 4	118 83	201	100.0

America (only data from these continents are at present available) is almost the same (Table 1)

The type of scoliosis and the severity of the curve was determined by clinical and radiological examination in the 201 scoliotic patients (Table 2). They were divided into six groups according to the angle of the curve (as given by Cobb)

(Table 2). Among curves over 30° only AIS (24 cases), congenital scoliosis (5 cases), scoliosis caused by rickets (2 cases) and paralytic scoliosis (1 case) were represented.

In the population examined there were slightly more females than males, ratio 1.102. Among the 201 cases of scoliosis the proportion of females was somewhat,

though not significantly, higher (1.14). In AIS, however, the female predominance became marked (1.21) and it increased proportionally with the severity of the curve (over 10°, the male/female ratio was 1:4).

REFERENCES

- Beals R K (1973) Nosologic and genetic aspects of scoliosis *Clin Orthop* **98** 32
- Filho N A & Thompson V W (1971) Genetic studies in scoliosis *J Bone Jt Surg* **53A** 199
- James J I P (1973) The etiology of idiopathic scoliosis *Israel J med Sci* **9** 705-710
- Kane W J & Moe J H (1970) A scoliosis prevalence survey in Minnesota *Clin Orthop* **69** 216-218
- Lettow F (1965) Probleme der Ätiologie und Therapie der idiopathischen Skoliose *Beitr Orthop* **12** 385-394
- Mau H (1972) Etiology of idiopathic infantile scoliosis *Reconstruct Surg Traim* **13** 184-190
- Neugebauer H (1972) Colb oder Ferguson Eine Analyse der beiden gebräuchlichsten Röntgenmessmethoden von Skoliosen *Z Orthop* **110** 342-356
- Shands A R & Eisberg H B (1955) The incidence of scoliosis in the state of Delaware. A study of 50 000 minifilms of the chest made during a survey for tuberculosis *J Bone Jt Surg* **37A** 1243-1249
- Wynne Davies R (1968) Familial (idiopathic) scoliosis. A family survey *J Bone Jt Surg* **50B** 24-30
- Wynne Davies R (1975) Infantile idiopathic scoliosis *J Bone Jt Surg* **57B** 138-141

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BLADDER FUNCTION AFTER HEMIPELVECTOMY

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Bladder function was studied in seven patients 5 to 100 months after hemipelvectomy. The urological investigation comprised: i) urography, micturition-cysto urethrography, cystoscopy, cystometry and urodynamic investigations in terms of simultaneous flow and pressure measurements. Hemipelvectomy was found not to give rise to disturbances in micturition.

Key words: hemipelvectomy, urodynamics, pressure, flow, urination, neurogenic bladder.

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Hemipelvectomy is performed where amputation is required because of malignant tumours in the pelvis or the upper femur. This extensive operation causes a variable, unilateral damage to the innervation of the urinary bladder.

Normal bladder function is dependent on an intact nervous system, consisting of autonomic, somatic and sensory pathways. The innervation of the detrusor is mainly parasympathetic, while the function of the sympathetic innervation of the trigone is still disputed. The parasympathetic nerves run from the sacral medulla segments II-IV (S_{II} – S_{IV}), to the pelvic plexus at the level of the lateral wall of the rectum where they branch to the ureterovesical region. The sensory innervation of the bladder comprises proprioception (stretch) and exteroception (pain), proprioception being by far the more important, as it is responsible for the micturition reflex and the sensation of bladder dilation. Some of these fibres follow the sympathetic hypogastric nerve

to the sympathetic trunk and the thoracolumbar medulla. The pelvic floor including the external sphincter receives somatic innervation from the pudendal nerve, which in addition is responsible for the sensory innervation of the urethra distal to the prostate. There is supposed to be unilateral innervation of the detrusor muscle and a complementary function of the three segments in the sacral medulla, with S_{III} as the most important. The sacral cord segments II-IV are the simple reflex arcs of the visceral and the somatic nerves, which are influenced by inhibitory and facilitative pathways from the medulla, cerebellum and cortex (Boss & Comarr 1971). In our patients, hemipelvectomy involves transection of the pudendal nerve, and in addition a risk of damage to the parasympathetic and sympathetic nerve supplies to the bladder at the periphery, where the nerve fibres are running in the pelvic and vesical plexus. We therefore consider it of some interest to examine the

though not significantly, higher (1.14). In AIS, however, the female predominance became marked (1.21) and it increased proportionally with the severity of the curve (over 10°, the male:female ratio was 1:3.4).

REFERENCES

- Beals R K (1973) Nosologic and genetic aspects of scoliosis *Clin Orthop* **88** 23-32
- Elilio N A & Thompson V W (1971) Genetic studies in scoliosis *J Bone Jt Surg* **53 A** 199
- James J I P (1973) The etiology of idiopathic scoliosis *Israel J med Sci* **9** 705-710
- Kane W J & Moe J H (1970) A scoliosis prevalence survey in Minnesota *Clin Orthop* **69** 216-218
- Lettow, F (1965) Probleme der Ätiologie und Therapie der idiopathischen Skoliose *Beitr Orthop* **12** 385-394
- Mau H (1972) Etiology of idiopathic infantile scoliosis *Reconstruct Surg Traum* **13** 191-190
- Neugebauer H (1972) Cobb oder Ferguson Line Analyse der beiden gebräuchlichsten Röntgenmessmethoden von Skoliosen *Z Orthop* **110** 342-356
- Shands A R & Isberg H B (1955) The incidence of scoliosis in the state of Delaware. A study of 50 000 minifilms of the chest made during a survey for tuberculosis *J Bone Jt Surg* **37 A** 1243-1249
- Wynne-Davies R (1968) Familial (idiopathic) scoliosis. A family survey *J Bone Jt Surg* **50 B** 24-30
- Wynne-Davies R (1975) Infantile idiopathic scoliosis *J Bone Jt Surg* **57 B** 138-141

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Table 3 Cystometry and simultaneous pressure and flow measurements in 7 patients 5-30 months after hemipelvectomy

Simultaneous pressure and flow measurements						
patient no	Cystometry	Micturition volume ml	Intravesical pressure prior to micturition mmHg*	Micturition pressure at maximum flow mmHg	Max flow ml/s	Detrusor function
1	normal	200	20	80	10	+
2	normal	450	15	60	21	+
3	normal	400	35	65	16	+
4	normal	480	30	100	24	+
5	normal	300	30	100	8	+
6	normal	200	not performed	22	15	+
7	normal	750	20	55	38	+

* 1 mmHg pressure = 1.36 cm H₂O pressure

Table 4 X ray investigation and cystoscopy

Patient no	MCU	Reflux	Irography	Cystoscopy
1	normal	—	asymmetric bladder	not performed
2	normal	—	asymmetric bladder	normal
3	normal	—	normal	normal
4	normal	—	normal	cystitis
5	narrow posterior urethra	—	prostate impression in the bladder base	posterior urethritis prostate hypertrophy
6	normal	—	normal	normal
7	normal	—	normal	normal

Urological follow-up examination comprised microscopy and bacteriological examination of urine serum creatinine determination iv urography micturition cysto urethrography (MCU) cystometry and urodynamic investigation (pressure flow study) MCU was performed in lateral projection in all patients three films being made one before one during and one after micturition. Bladder configuration was evaluated from a bladder filling picture in iv urography and from cystoscopy.

The urodynamic studies were performed as described by Iversen Hansen (1973) and the parameters measured are indicated in Tables 2 and 3. The patients were asked to attend the examination with a full bladder and a spontaneous micturition curve was recorded using a flowmeter. A thin catheter was inserted into the bladder by the transurethral route and the residual urine was measured. A thin catheter was also inserted into the rectum and pressures

were recorded in both the bladder and the rectum. Successive pressure estimations were made after each instillation of 50 ml saline in the bladder both "first sensation" and "definite sensation of fullness" (cystometric capacity) being recorded. The final pressure-flow study was performed after the bladder was filled through the transurethral catheter, pressures and flow being recorded simultaneously during micturition.

RESULTS

Table 2 shows the results of the examination of spontaneous micturition. All patients had maximum flow within the normal range. This was also the case in patients Nos 2 and 5, who on examination

Table 1 Age and sex, tumour diagnosis and time of urological follow-up in 7 patients submitted to hemipelvectomy

Patient no	Age	Sex	Tumour diagnosis	Type of operation*	Urological follow up in months post operation
1	13	M	osteogenic sarcoma of the femur	A	10
2	17	M	osteogenic sarcoma of the pelvis	A	5
3	26	M	osteogenic sarcoma of the femur	A	72
4	29	M	osteogenic sarcoma of the pelvis	A	31
5	41	M	neurofibrosarcoma of the pelvis	B	90
6	25	F	chondrosarcoma of the pelvis	A	31
7	54	F	osteogenic sarcoma of the femur	B	44

* cf text operative procedure

Table 2 Spontaneous micturition in 7 patients 5 to 90 months after hemipelvectomy

Patient no	Maximal flow ml/s (micturition vol ml)	Residual volume (ml)	Urinary culture
1	21 (320)	0	sterile
2	22 (100)	0	sterile
3	19 (200)	0	sterile
4	24 (260)	50	sterile
5	17 (120)	0	sterile
6	21 (330)	90	sterile
7	35 (400)	0	sterile

bladder function in a number of patients who have undergone hemipelvectomy

MATERIAL AND METHODS

Patients The material consists of the seven surviving patients out of 23 patients who underwent hemipelvectomy in the Department of Orthopaedic Surgery at the University Hospital during the period 1964-1972. Table 1 shows age, sex and preoperative tumour diagnosis. None of the patients had any urological symptoms before operation. All patients were hospitalized for follow-up examination. The period from hemipelvectomy to urological follow up examination varied from 5-90 months (Table 1).

Operative technique in hemipelvectomy Hemipelvectomy was performed as described by previous authors (Gordon-Taylor & Monroe 1952; Bertelsen & Meyer 1961; Ravitch & Wilson 1964; Den Otter 1972). Anteriorly, the pelvis was divided near or in the symphysis and posteriorly through the greater sciatic notch and up over the iliac crest, more or less close to the sacro iliac

joint. The iliac vessels were exposed anteriorly together with the ilio-psoas muscle. The femoral nerve and obturator nerve were transected from the inside of the pelvis, while posteriorly the sciatic nerve was transected where it emerges from the pelvic cavity through the foramen in frapiriformis. The pudendal nerve was transected together with the sacro-tuberous ligament and the sacro spinous ligament. After dividing the pelvic wall, the bladder and rectum were exposed medially, employing blunt dissection in the paravesical and pararectal connective tissue space. During this dissection the pelvic plexus (i.e. the inferior hypogastric plexus) and the vesical plexus are in danger of damage. In five patients the hemipelvectomy was performed by transection of the pelvis anteriorly in the symphysis and posteriorly immediately lateral to the sacro-iliac joint (type A, Table 1). A slightly less radical intervention was carried out in two patients: the resection line anteriorly in the bone lying 2 cm lateral to the symphysis and posteriorly from the greater sciatic notch to midway between the superior and inferior anterior iliac spine (type B, Table 1).

- Baumrucker G B & Shaw J W (1953) Urologic complications following abdominoperineal resection of the rectum *Arch Surg* 67 502-513
- Bertelsen A & Meyer J (1961) Hemipelvectomi *Nord Med* 66 351-356
- Bors F & Comarr A P (1971) *Neurological urology* S Karger AG Basel
- Bowers J E, Moekkel C W, Yates G L & Wesson H R (1957) A study of bladder function following vaginal hysterectomy *Surg Gynec Obstet* 104 287-294
- Dea Otter G (1972) Hemipelvectomy *Arch Chir Veet* 21 263-269
- Eickenberg H U, Amin M, Klompus W & Lich H Jr (1976) Urologic complications following abdominoperineal resection *J Urol* 115 180-182
- Frisson A O, Hellström B, Vergårdh A & Ruhde I (1970) Unilateral neurological deficit in myelomeningocele with normal bladder function *Acta paediat scand* 59 487-490
- Gordon Taylor C & Monro B (1952) The technique and management of hindquarter amputation *Brit J Surg* 39 536-541
- Gunterberg B, Norlén L, Stener B & Sundin T (1975) Neurologic evaluation after resection of the sacrum *Invent Urol* 12 183-188
- Held F (1974) Neurologischen Komplikationen nach abdominal erweiterter Hysterektomie *Arch Gynaekol* 217 37-68
- Iversen Hansen R (1973) *Cryo prostatectomy. A clinical and hydrodynamic investigation* (Disp.) F.A.D.L.s Forlag A/S Copenhagen
- Himmel D L (1976) Urinary bladder function in rats following regeneration of direct and crossed nerve anastomoses *Chicago Med School Q* 26 1-12
- Kontturi M J, Larmi T K & Tuononen E (1974) Bladder dysfunction and its manifestations following abdominoperineal extirpation of the rectum *Ann Surg* 179 179-182
- Ravitch M M & Wilson T C (1964) Long term results of hemipelvectomy *Ann Surg* 159 667-682
- Roman Lopez J J & Barclay D L (1973) Bladder dysfunction following Shauta hysterectomy *Amer J Obstet Gynec* 115 81-90
- Tank, F S, Ernst C B, Woolson S T & Lapides J (1972) Urinary tract complications of anorectal surgery *Amer J Surg* 123 118-122
- Ward J N & Ray H R (1972) Immediate and delayed urologic complications associated with abdominoperineal resection *Amer J Surg* 123 642-646

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had micturition volumes less than the value usually required for evaluation of maximum flow.

Cystometry (Table 3) showed in all cases normal pressure during filling without uninhibited contractions or low pressure filling curve, i.e. without signs of neurogenic bladder dysfunction. Simultaneous pressure flow measurement showed normal premicturition pressure in all patients except No. 6, whose pressure was not measured because of a fault in the apparatus. Micturition pressure at maximum flow was found to be elevated in two cases (patients Nos. 4 and 5, Table 3). Patient No. 1 showed pronounced inflammatory changes in the bladder on cystoscopy, which might explain the elevated micturition pressure. In patient No. 5, the elevated micturition pressure together with the low flow and the elevated residual urine suggest infravesical obstruction. Infravesical obstruction not caused by hemipelvectomy was confirmed by MCU, by urography and cystoscopy (Table 1). In patient No. 7 both spontaneous micturition examination (Table 2) and determination of simultaneous pressure and flow (Table 3) showed a large micturition volume 750 ml on first investigation. The other parameters in this patient were found to be normal. An MCU investigation could show no reflux in any of the patients (Table 4). In two cases urography showed that the bladder was asymmetrical (patients Nos. 1 and 2, Table 1). Cystometry and urodynamic investigation showed no signs of denervation of the bladder in these patients.

DISCUSSION

Following major operations in the true pelvis e.g., extirpation of the rectum and radical hysterectomy, disturbances of micturition may often arise as a result of damage to the innervation of the bladder

(Brumrucker & Shraw 1953, Bowers et al 1957, Bors & Comarr 1971, Tank et al 1972, Ward & Ny 1972, Roman Lopez & Barclay 1973, Held 1974, Konturi et al 1974, Barclay & Roman Lopez 1975, Lickenberg et al 1976). In these types of operation it may be assumed that there has been bilateral damage to the pelvic plexus resulting in infranuclear bladder paresis. In hemipelvectomy, damage to the nerve supply to the bladder is strictly unilateral, but presumably involves both the pelvic plexus and the pudendal nerve. As the present follow-up investigation shows, unilateral denervation of the bladder does not result in neurogenic bladder dysfunction. The result of our investigation is in accordance with animal investigations and with human investigations involving procedures other than hemipelvectomy. Kimmel (1966) has reported that in rats only one pelvic nerve is necessary to maintain good bladder function. Ericsson et al (1970) found normal bladder function in patients with myelomeningocele causing unilateral neurological defects. Gunterberg et al (1975) showed that resection of the sacrum with unilateral lesion of sacral nerves 1 to 5 did not abolish the micturition reflex. It is possible that by employing electrical stimulation of the detrusor muscle electromyography or a denervation hypersensitivity test with carbacholine the presence of unilateral denervation could have been demonstrated in the present investigation.

It may be concluded from the present investigation that hemipelvectomy with possible unilateral denervation of the bladder does not give rise to clinically or urodynamically recognisable disturbances in micturition.

REFERENCES

- Barclay D I & Roman Lopez J J (1975) Bladder dysfunction after subtotal hysterectomy. *Amer J Obstet Gynec* 123 519-526.

- Baumrucker G O & Shaw J W (1953) Urologic complications following abdominoperineal resection of the rectum *Arch Surg* 67 502-513
- Bertelsen A & Meyer, J (1961) Hemipelvectomy *Nord Med* 66 351-356
- Bors E & Cornart A E (1971) *Neurological urology* S Karger AG Basel
- Bowers J E, Moeckel C W, Yates G L & Weston H R (1957) A study of bladder function following vaginal hysterectomy *Surg Gynec Obstet* 104 287-294
- Den Otter G (1972) Hemipelvectomy *Arch Chir (Paris)* 263-269
- Fickelberg H U, Amin M, Klompus W & Lich H Jr (1976) Urologic complications following abdominoperineal resection *J Urol* 116 180-182
- Ersson U O., Hellstrom B, Bergårdh A & Rohde U (1970) Unilateral neurological defect in myelomeningocele with normal bladder function *Acta paediat scand* 59 487-490
- Gordon Tavler G & Monroe R (1952) The technique and management of hindquarter amputation *Brit J Surg* 39 536-541
- Gunterberg B, Norlén L, Stener B & Sundin T (1975) Neurologic evaluation after resection of the sacrum *Invest Urol* 13 183-188
- Held E (1974) Die urologischen komplikationen nach abdominal erweiterter Hysterektomie *Arch Gynaekol* 217 37-68
- Iversen Hansen R (1973) *Cryo prostatectomy A clinical and hydrodynamic investigation* (Disp) TADL s Forlag A/S Copenhagen
- Kimmel D L (1966) Urinary bladder function in rats following regeneration of direct and crossed nerve anastomoses *Chicago Med School Q* 26 1-12
- Kontturi M J, Larmi T K & Tuononen S (1974) Bladder dysfunction and its manifestations following abdominoperineal extirpation of the rectum *Ann Surg* 179 179-182
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- Tauk E S, Ernst C, B Woolson S T & Lapidus J (1972) Urinary tract complications of anorectal surgery *Amer J Surg* 123 118-129
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It may be concluded from the present investigation that hemipelvectomy, with possible unilateral denervation of the bladder, does not give rise to clinically or urodynamically recognizable disturbances in micturition.

REFERENCES

- Barclay D I & Roman Lopez J J (1975) Bladder dysfunction after Shauta hysterectomy.
Amer J Obstet Gynec 123 519-526

Clinical examination of newborn babies was performed in the nursery between the second and sixth day of age. A follow up study of these babies was made in pediatric and orthopedic clinics. The clinical examination consisted of observation and manual examination of the hips. The diagnosis was confirmed in every case by radiography. In this study all babies exhibiting hip pathology were born in the occiput presentation. It is also important to emphasize that in all the cases there were no associated congenital deformities. The treated infants have been followed for an average of 20 months. During this period we have carried out clinical and laboratory studies on all the mothers of these infants because of an unexpected observation: all mothers of the infants with LAH were suffering from thyroid disorders. All these mothers have been examined and given thyroid tests.

In order to be also able to evaluate the maternal thyroid disorders in association with neonatal hip pathology, muscle specimens taken from the affected hips of all 10 infants were studied histologically. Some specimens of shoulder muscles taken from the same infants were used as control specimens. The criterion for dividing the mothers into two series was the clinical form of congenital hip pathology in the infants. Two clinical forms were clearly distinguished. These were (a) LAH and (b) AD. In the same way, a second unselected criterion arose viz., the family history. It is of some interest that accurate family history has been obtained with negative results for the first group in contrast to the second where a positive family history has been observed for all cases. This point has been systematically studied. Thus the first series consisted of 10 mothers who had children with LAH and a negative family history for this condition. The second series concerned 9 mothers whose infants were afflicted with AD. In this series all cases showed a positive family history of hip disorder. All mothers came from the same geographic area. The age distributions in both series were approximately the same.

FINDINGS

Group I

A Mothers who had infants with LAH and a negative family history. The thyroid gland was enlarged in every mother. Tests of thyroid function revealed the following:

- 1 Out of six women with clinically suspected thyroid hyperfunction, three had hyperthyroidism caused by a hyperfunctioning adenoma, one had Graves' disease and two had undergone thyroid operations for toxic goiter. Three of the latter had had a poor outcome of previous pregnancies.
- 2 Autonomous thyroid nodule was diagnosed in two mothers.
- 3 In one mother the thyroid gland was multinodular and biopsy examination revealed changes of papillary adenocarcinoma in some areas.
- 4 One mother had euthyroid goiter.

B Affected infants. Ten infants with clinical signs of LAH to 45° at birth were not treated for 3 months to see what would happen. The first infant developed hip dislocation at 3 months of age. The child was then treated with traction, closed reduction and hip spica. Four babies developed hip subluxations at 1½ months of age and were treated with Frejka pillows for a period of 5 months. The other five were checked at 3 months of age. Paradoxically, the author had an unpleasant surprise. After this period the hips were abnormal clinically and X-ray showed epiphyseal dysplasia bilaterally. These hips were severely affected. The epiphyseal nuclei were completely destroyed whereas the acetabulae were well formed. In this group, early appearance of the upper femoral epiphysis was a common feature. The time of appearance of the ossification center ranged from 3 to 6 weeks. In no case was there any family history of hip disorder.

Histological examination. The morphology (using light microscopy) of muscle specimens from the 10 infants suffering from LAH was studied. The specimens were from the pelvifemoral, the pelvutrochanteric, and the gluteal groups. A total of 30 specimens (one from each

LIMITATION OF ABDUCTION OF HIPS IN THE NEWBORN

Is It A Clinical Sign or a Phenocopy of Congenital Hip Dislocation?

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Until recently the possibility of a connection between maternal thyroid disorders and congenital hip pathology in the newborn has not been given any attention. However, from this study it is evident that there is a close relationship between maternal thyroid disorders and limitation of abduction of the hips in the newborn. The histological findings are suggestive of a neonatal thyrotoxic myopathy or periodic paralysis which might give rise to an error in muscle balance around the hips. The high proportion of affected children without a family history of congenital hip dislocation suggests that genetic factors have in the past been overemphasized.

Key words limited hip abduction, phenocopy, thyrotoxic myopathy

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Congenital hip dislocation (CDH) is an important abnormality partly because it is so frequent. In recent years many studies have attempted to demonstrate the etiology of this common deformity. The genetics of CDH is considered complex. At the present time, the inclination is to accept multifactorial inheritance for this defect, as has been done by several geneticists. However, the causation of CDH is thoroughly confused and many questions remain unanswered. In the present study, attention has been focused on the possible relationship between maternal thyroid disorders and neonatal hip pathology. Work in this field has been stimulated by the incidence of thyroid disorders in mothers whose newborn babies had limitation of abduction of the hips (LAH). A muscular histopathology tending to be more obscure in infants with LAH was first described

by Matsoukas et al in 1969. The author has made an effort to classify these abnormalities and to introduce them as a factor in the pathology of LAH. It might be noted that in Greece, a complete overlapping between areas of CDH and regions of thyroidopathies is observed. It seems to be true that the same phenomenon is found worldwide.

MATERIAL AND METHOD

During the period 1967 to 1975 the hips of 2000 newborn babies were examined. Among the 2000 newborns congenital hip pathology was detected in 19 babies (15 female, 4 male). This material was classified into two groups: (a) Ten female infants with LAH. One of them had unilateral CDH, four developed bilateral hip subluxation and five exhibited severe epiphyseal dysplasia bilaterally without subluxation or dislocation. (b) Nine infants (5 female, 4 male) with acetabular dysplasia (AD) with hips dislocated or 'good hip' at risk.

Clinical examination of newborn babies was performed in the nursery between the second and sixth day of age. A follow up study of these babies was made in pediatric and orthopedic clinics. The clinical examination consisted of observation and manual examination of the hips. The diagnosis was confirmed in every case by radiography. In this study all babies exhibiting hip pathology were born in the occiput presentation. It is also important to emphasize that in all the cases there were no associated congenital deformities. The treated infants have been followed for an average of 20 months. During this period we have carried out clinical and laboratory studies on all the mothers of these infants because of an unexpected observation: all mothers of the infants with LAH were suffering from thyroid disorders. All these mothers have been examined and given thyroid tests.

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FINDINGS

Group I

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muscle group) was examined. Three facts emerged from this study: a) There was muscular degeneration in all cases, b) The degeneration was more severe in younger children, c) There was considerable alteration in the muscles of the gluteal group.

Almost all the specimens from the shoulder muscles showed the same histopathology, viz., variations in muscle fiber size, swelling, loss of myofibrils, vacuolization, and residual sarcolemmal nuclei. The most constant finding was the vacuolization of the muscle fiber. These findings are identical to those which occur in thyrotoxic myopathy. It is well known that various myo-thyroidien syndromes show a predilection for the proximal girdle musculature (Kissel et al 1965, Danowski 1969).

Group II

A Mothers who had infants with AD and a positive family history. The clinical and laboratory surveys of the nine mothers with a positive family history of CDH uncovered only two with a thyroid condition. Both of them had simple goiterous enlargement, which functionally proved to be euthyroid.

B Affected infants. These dislocations were diagnosed at the age of 4-5 months. All dislocated hips were associated with dysplastic acetabulae. In addition, there were two cases of bilateral acetabular dysplasia, with the "good hip" at risk.

Follow-up of these infants who had an acetabular index of over 28° and absence of the acetabular beak has not revealed spontaneous healing of the acetabular defect. Five biopsied hips showed little organic change in the muscles. Despite prolonged conservative treatment the epiphyseal nuclei are normal

and tiredness 6 months after a previous pregnancy. The thyroid was diffusely enlarged and a fine tremor of the hands was present. Her serum PBI level was greater than 11 µg/100 ml (normal range 7.5 to 8 µg). Radioisotope studies revealed diffuse uptake in normal tissue in both hyperplastic lobes of the thyroid. Her first two infants had been normal whereas the third, a girl, had L III Hip radiographs taken at the age of 3 days did not reveal any abnormality. No treatment was given. A ray taken after some months showed that both nuclei of ossification were completely fragmented. Acetabulae were well formed.

Case 2 (Group I). A 31 year old woman underwent subtotal thyroidectomy for toxic goiter in 1972. Two years later she became pregnant for the first time. This was terminated by cesarean section because of cephalopelvic disproportion. The infant has L III and a nontoxic goiter. At the age of 1 year her hips were found to be severely affected. No splintage was used. A ray of the pelvis demonstrated epiphyseal dysplasia bilaterally. Acetabulae were well formed.

Case 3 (Group I). A 24 year old woman had noticed a lump in her neck 4 years previously. Clinical and laboratory studies confirmed the diagnosis of multinodular goiter. Biopsy revealed changes of papillary adenocarcinoma. Her child, a girl, and the product of a normal full term pregnancy was born with L III. Both hips were subluxated. Although no treatment was given spontaneous reduction took place after 2 months. Acetabulae are well developed.

DISCUSSION

It is well known that the relative significance of genetic and exogenous factors varies from disease to disease and perhaps even from case to case. All disease can be viewed as being part of a spectrum in this regard (McKusick 1969).

It has also been said that all disease has its causation. In almost all of the common malformations, such as CDH, the genetic component in the etiology is polygenic. That is to say it involves genes at several gene loci. What do we know about the etiology of CDH? It has been suggested by some, including Wynne Davies (1971) and Carter & Furber (1971) that the genetic factors are probably related to joint laxity and to

CASE REPORTS

Case 1 (Group I). A 29 year old woman developed progressive nervousness, palpitations

acetabular dysplasia, while the environmental factor which "triggers off" the dislocation in many cases is probably related to the breech malposition. On the other hand, there is no example of polygenic inheritance in man which actually has been analyzed by a satisfactory method. This is simply due to the fact that the methods used to elucidate polymeric inheritance are not applicable to man (Ienz 1961). A sporadic case of a malformation which is known to be inherited in some families may thus represent a phenocopy. The distribution is important, since, if a genetic change is involved the probability of recurrence of the malformation in the family may be quite high, but if the malformation is a phenocopy the chance of recurrence will depend only on the chance of recurrence of the causal environmental factor, which may be extremely remote. However, the causes of a phenocopy are not apparent and this fact can lead to deceptive interpretation of family histories.

Perhaps the fluidity and confusion of confidences about the etiology of CDH might be attributed to this fact. From this study there is already evidence that a large proportion of sporadic neonatal cases are phenocopies. The present writer suggests that clinical material either as neonatal or late-diagnosis cases could well be a conglomeration of hereditary cases and phenocopies. If this etiologic model is accepted further investigations in this field become extremely interesting.

Conclusions

From this study of both mothers and infants, although it comprises a very small sample and is not statistically sig-

nificant, it can be seen that limitation of abduction of the hips is a distinct variety of dislocation rather than a controversial clinical sign of it. The validity and significance of the histological findings are obvious. They are suggestive of a hitherto undescribed correlation between non-familial limited hip abduction and maternal thyroid disorders. In this variety an error in muscle balance around the hips might be attributable to a reversible thyrotoxic myopathy. However, this matter is still awaiting elucidation.

ACKNOWLEDGEMENTS

I wish to express my deep appreciation and thanks to Professors H. Ikkos and D. Koutras, two experts in thyroid disease, for their help and for the complete endocrinologic study of our clinical material made by them. I also wish to thank Assistant Professor of Pathology D. Papadimitriou for his careful examination of the specimens.

REFERENCES

- Carter, C. & Fairbank, T. (1974) The genetics of locomotor disorders. *Oxford monographs on medical genetics* 1, 92-95.
- Danowski, S. T. (1969) *Clinical endocrinology* Vol. II, p. 132. The Williams & Wilkins Co. Baltimore.
- Kissel, P., Hartemann, P. & Duc, M. (1965) *Les syndromes myo thyroïdiens* n° 32. Masson & Cie, Paris.
- Lenz, W. (1961) *Human genetics* pp. 150-152. University of Chicago Press.
- Matsoukas, J., Papadimitriou, D. & Euthymiou, C. (1969) Étude histologique des muscles pelvi-fémoraux chez les enfants porteurs d'une luxation congénitale de la hanche. *Helo paediat Acta* 24, 201-207.
- McKusick, V. (1969) *Medical genetics*. Second edition, p. 189. Foundations of modern genetics series. Prentice Hall, Inc., Englewood Cliffs, New Jersey.
- Wynne Davies, H. (1973) *Heritable disorders in orthopaedic practice* pp. 193-196. Blackwell Scientific Publications, Oxford.

muscle group) was examined. Three facts emerged from this study: a) There was muscular degeneration in all cases, b) The degeneration was more severe in younger children, c) There was considerable alteration in the muscles of the gluteal group.

Almost all the specimens from the shoulder muscles showed the same histopathology, viz., variations in muscle fiber size, swelling, loss of myofibrils, vacuolation, and residual sarcolemmal nuclei. The most constant finding was the vacuolation of the muscle fiber. These findings are identical to those which occur in thyrotoxic myopathy. It is well known that various myo-thyroidien syndromes show a predilection for the proximal girdle musculature (Kissel et al 1965, Danowski 1969).

Group II

A Mothers who had infants with AD and a positive family history. The clinical and laboratory surveys of the nine mothers with a positive family history of CDH uncovered only two with a thyroid condition. Both of them had simple goiterous enlargement, which functionally proved to be euthyroid.

B Affected infants. These dislocations were diagnosed at the age of 4-5 months. All dislocated hips were associated with dysplastic acetabulae. In addition, there were two cases of bilateral acetabular dysplasia, with the "good hip" at risk.

Follow-up of these infants who had an acetabular index of over 28° and absence of the acetabular beak has not revealed spontaneous healing of the acetabular defect. Five biopsied hips showed little organic change in the muscles. Despite prolonged conservative treatment the epiphyseal nuclei are normal.

CASE REPORTS

Case 1 (Group I). A 29 year old woman developed progressive nervousness, palpitations

and tiredness 6 months after a previous pregnancy. The thyroid was diffusely enlarged and a fine tremor of the hands was present. Her serum PBI level was greater than 11 $\mu\text{g}/100\text{ml}$ (normal range 3.5 to 8 μg). Radioiodine studies revealed diffuse uptake in normal tissue in both hyperplastic lobes of the thyroid. Her first two infants had been normal whereas the third, a girl, had LAM. Hip radiographs taken at the age of 3 days did not reveal any abnormality. No treatment was given. A ray taken after some months showed that both nuclei of ossification were completely fragmented. Acetabulae were well formed.

Case 2 (Group I). A 31 year old woman underwent subtotal thyroidectomy for toxic goiter in 1972. Two years later she became pregnant for the first time. This was terminated by cesarean section because of cephalopelvic disproportion. The infant has LAM and a nontoxic goiter. At the age of 1 year her hips were found to be severely affected. No splintage was used. A ray of the pelvis demonstrated epiphyseal dysplasia bilaterally. Acetabulae were well formed.

Case 3 (Group I). A 24 year old woman had noticed a lump in her neck 4 years previously. Clinical and laboratory studies confirmed the diagnosis of multinodular goiter. Biopsy revealed changes of papillary adenocarcinoma. Her child, a girl, and the product of a normal full term pregnancy, was born with LAM. Both hips were subluxated. Although no treatment was given, spontaneous reduction took place after 3 months. Acetabulae are well developed.

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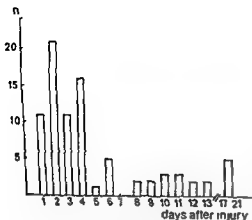


Figure 1 Interval between accident and arthroscopy. In some patients treated initially at other hospitals arthroscopy was delayed.

surgeon. The procedure was always included in the normal operation list so that immediate operation could be carried out if necessary.

Technique of arthroscopy

Our technique has been described earlier (Gillquist & Hagberg 1976). No tourniquet was used. The 5 mm Storz arthroscope (Stille Werner Sweden) is introduced into the suprapatellar bursa through the patellar tendon. Sterile water is flushed through the joint by an infusion pump (Sarns Model 6500 Stille Werner Sweden) and allowed to escape through a special needle (arthroscopy cannula Stille Werner, Sweden) inserted into the suprapatellar bursa. About 2000 ml is required. Hooks (Gillquist & Hagberg 1976) are used to test the menisci and the ligaments. When indicated by the findings at arthroscopy arthrotomy is performed at the same session.

PATIENTS

During the period 1972 to 1975 we performed 84 arthroscopies on 84 consecutive patients (66 men and 13 women) in the acute period after a knee injury. The age of the patients ranged between 15 and 60 years and most (55 patients) were between 15 and 30. Soccer was a prominent cause of injury and together with other sports accounted for 63 per cent of all cases.

Time of arthroscopy (Figure 1)

Seventy per cent of the arthroscopies were performed within the first 4 days after the

accident. In some cases the interval was longer as the patients had first been treated at other hospitals. These patients also fulfilled the criteria of haemarthrosis or locking.

RESULTS

Figure 2 shows the diagnosis arrived at during arthroscopy or arthrotomy. The anterior cruciate ligament was injured in 50 per cent of the injured knees. Combined injury of the anterior cruciate ligament, medial meniscus, and the medial collateral ligament was the commonest finding. In fact, combined injuries were the rule. Acute locking of the joint was an unreliable sign of meniscus lesion. Out of 28 patients with a locked knee only 12 showed tears of the meniscus (10 medial and 2 lateral). Most others showed partial rupture of the medial collateral ligament.

Haemarthrosis

Haemarthrosis was present in 69 arthroscopies (Table 1). The commonest

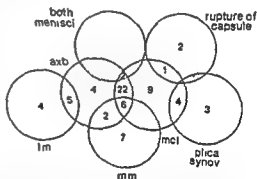


Figure 2 Diagram showing the combination of injuries found at 84 arthroscopies. There were also three patients with rupture of the posterior cruciate ligament, two with dislocation of the patella, seven with a chondral fracture, and one with a ruptured patellar tendon strip after reconstruction of the anterior cruciate ligament. Two patients with rupture of the anterior cruciate ligament and lateral meniscus also showed partial rupture of the medial collateral ligament. Ten showed partial rupture of the anterior cruciate ligament. (For abbreviations see text to Table 3.)

ARTHROSCOPY IN ACUTE INJURIES OF THE KNEE JOINT

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Arthroscopy was performed during the acute phase of injury in 11 knees (79 patients). A satisfactory view of the joint was obtained in all cases, and no complications occurred. About two thirds of the patients had injuries associated with violent rotation/abduction. In about one third of the patients operation could be avoided. In cases with haemarthrosis, serious ligament injury was present in nearly 50 per cent. Complete arthroscopy was associated with few diagnostic errors. Clinical examination often led to uncertain or incorrect diagnosis even when performed under anaesthesia by experienced surgeons. In contrast, arthroscopy led to rapid diagnosis and treatment thus shortening the period of disability. We recommend arthroscopy in acute knee injuries, but the examination must be performed by an experienced arthroscopist.

Key words endoscopy, arthroscopy, knee injury, knee joint haemarthrosis

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Early diagnosis of injuries of the knee joint is of great importance, in order to prevent disability (Liljedahl & Nordstrand 1969, Alm 1974). However, common diagnostic methods often fail during the acute stage of a knee injury (Liljedahl et al 1965). In recent years arthroscopy has been used with great success in diagnosis of non-acute cases of knee joint trauma or disease (Jackson & Abe 1972, Dandy & Jackson 1975, Casscells 1971, Wruhs 1970, Watanabe et al 1968, Gallannaugh 1973, Alm et al 1974, Gillquist & Hagberg 1976). Jackson (1974) and O'Connor (1974) reported that arthroscopy might be of value in acute injuries. Some preliminary experiments with arthroscopy in the acute stage (Gillquist & Hagberg 1976) led us to test the technique in a larger series of consecu-

tive patients over the past few years. This paper summarizes our experiences.

METHODS

Indications for arthroscopy

Patients admitted to the emergency department with acute knee injury with haemarthrosis or acute locking with effusion were included. Locking was defined as an extension defect with an elastic resistance against forced extension. The diagnosis of haemarthrosis was made when swelling of the joint took place immediately after trauma and blood was aspirated from the joint. Patients were examined on admission immediately after aspiration of the distended joint. A preliminary diagnosis was made, and the patient was admitted to hospital. Straight X-ray films were always taken on admission.

Arthroscopy was carried out as soon as possible after admission, usually within a few days by an experienced arthroscopist, the joint being first examined under general anaesthesia by the

Table 3 Number of patients with different diagnoses included in groups I-III

Type of injury	Group I Operation avoided	Group II Change of surgical procedure	Group III Arthroscopy superfluous	Total
acl (partial rupture) + mcl	4	5	1	10
acl + mm	—	—	2	2
acl + lm	1*	1	1	3
acl + mcl + mm	—	2	4	6
acl + mcl + lm	—	1	1	2
acl + mcl + mm + lm	—	1	1	2
acl (3 with fracture)	—	2	2	4
mcl (1 capsular rupture)	9	—	1	10
mm	—	3	4	7
lm (1 with fracture)	—	4	—	4
plica synovialis (+ 3 with mcl)	6	—	1	7
pcl	—	3	—	3
osteocondral fracture	4	1	2	7
capsular rupture	1	—	1	2
patellar dislocation	1	1	—	2
rupture of reconstructed anterior cruciate ligament	—	1	—	1
Total	26	31	27	84

* This patient showed partial rupture of the anterior cruciate ligament a small rupture of the lateral meniscus and severe osteoarthritis. Operation was not performed.

acl = the anterior cruciate ligament mcl = medial collateral ligament mm = medial meniscus
lm = lateral meniscus pcl = posterior cruciate ligament

rupture of the lateral meniscus was also overlooked. In these cases indication for operation had already been established by the arthroscopic demonstration of a ruptured anterior cruciate ligament.

Misinterpretation and technical errors

This group comprises three patients subjected to unnecessary operations. The first patient with a rupture of the plica lata was erroneously operated on with a diagnosis of rupture of the anterior cruciate ligament. In another patient with a fracture of the eminentia intercondyloidea without dislocation a small rupture of the medial meniscus was diagnosed at arthroscopy. During arthrotomy, however, the rupture was found to be insignificant.

The third patient had a linear rupture of the capsular attachment of the medial

meniscus diagnosed at arthroscopy. During operation a rupture of the capsule was seen but the meniscus was thought to be intact. However, the patient had to be subjected to reoperation after further trauma a few months later. He then showed a dislocated medial meniscus. The significance of the arthroscopic finding had thus been underestimated during the first operation.

Diagnostic value of arthroscopy

The diagnosis arrived at during arthroscopy was compared with the diagnosis made after X-ray examination (mostly straight films) and clinical examination under anaesthesia by an experienced surgeon. The patients were arranged in three groups according to the diagnostic contribution made by arthroscopy in each case. Group I consists of

finding was rupture of the medial collateral ligament in combination with tearing of the anterior cruciate ligament. Rupture of the anterior cruciate ligament was present in 64 per cent of the 69 cases with haemarthrosis. However, the rupture was partial and did not necessitate operation in 10 cases. Rupture of the medial collateral ligament was diagnosed by valgus instability, and at arthroscopy a wide medial recess or haemorrhage from the ruptured medial synovium was found. In some cases rupture of the deep portion of the ligament could be demonstrated. The arthroscopic findings do not permit differentiation of partial and total ruptures of the medial collateral ligament, however, and this was done by testing the valgus instability. In seven cases a rupture of the plica synovialis was found to be the sole source of the haemarthrosis, and this together with partial rupture of the medial collateral ligament was present in five cases. Rupture of the joint capsule was an uncommon cause of haemarthrosis.

Table 1 Injuries in patients showing haemarthrosis (n = 69). In many cases the various injuries occurred in combination (see also Figure 2)

Type of injury	n	Per cent
Total rupture of the anterior cruciate ligament	31	45
Partial rupture of the anterior cruciate ligament	10	14
Total rupture of the posterior cruciate ligament	2	3
Total or partial rupture of the medial collateral ligament	41	59
Rupture of a meniscus	16	23
Osteochondral fracture	7	10
Dislocation of the patella	2	3
Rupture of the plica synovialis	7	10
of the anterior cruciate ligament)	3	4
	1	

Table 2 Diagnosis at arthroscopy or arthrotomy in 15 patients without haemarthrosis

Diagnosis	No
Rupture of	
medial meniscus	7
lateral meniscus	3
medial collateral ligament	4
posterior cruciate ligament	1
Total	15

Cases with no haemarthrosis

The diagnosis in these 15 cases is shown in Table 2. The commonest lesion was ruptured meniscus. One patient showed rupture of the tibial insertion of the posterior cruciate ligament without haemarthrosis. There were no ruptures of the anterior cruciate ligament in this group.

Follow-up examination

In 30 patients arthroscopy was not followed by operation. They were followed up for 1 year and most regained full activity. In two patients total rupture of the anterior cruciate ligament and partial rupture of the medial collateral ligament were not treated by operation. In one of them arthroscopy was performed under epidural anaesthesia and the patient wished to postpone operation. The other was an obese, 40 year-old woman, alcoholic, injured while drunk. Apart from the cruciate ligament injury she also had severe osteoarthritis. Operation was not considered to be indicated. In both cases the knee joint was unstable and the patients were disabled at the follow-up examination.

Diagnostic errors

In five cases (9 per cent) there was some lack of correlation between the arthroscopic picture and the findings at operation. In four of these a linear rupture of the posteromedial part of the medial meniscus was not diagnosed. One

cruciate ligament at its normal site often led us to the diagnosis. Moreover after some days arthroscopy becomes more difficult as the blood in the joint causes synovitis and the bulging synovia often tends to obstruct the field. Because of these problems arthroscopy of an acute knee injury should only be undertaken by a surgeon with great experience of arthroscopy in non acute cases.

The fact that haemarthrosis is a sign of serious injury is demonstrated by the present series. In 46 per cent of patients with haemarthrosis a lesion of the anterior cruciate ligament was present in association with partial rupture of the medial collateral ligament and sometimes also with rupture of the meniscus (the unhappy triad O'Donoghue 1950). However in 10 of these patients only a partial rupture of the anterior cruciate ligament was found. The unhappy triad leads to permanent disability if left untreated (Alm 1974) and treatment is more complex if delayed (O'Donoghue et al 1966, Brostrom et al 1968, Gillquist et al 1971, Alm et al 1974). If all our patients had been initially

patients with haemarthrosis rupture of a meniscus was usually combined with lesions of the ligaments whereas when a haemarthrosis was present a single rupture of a meniscus was the commonest finding. Rupture of the joint capsule alone was an infrequent cause of haemarthrosis. The conclusion is therefore that a patient with haemarthrosis should be regarded as having a serious ligament injury until this has been disproved.

Our series also demonstrates the insufficiency of clinical examination even when performed under anaesthesia by an experienced surgeon. In fact even when we later judged the arthroscopy to have been superfluous many of the patients

could not have been safely distinguished from the other groups by clinical examination alone. However the clinical diagnosis was always correct when marked instability was present. Thus in such cases arthroscopy seems unnecessary. This series includes some patients in whom more than one experienced surgeon clinically diagnosed rupture of the medial meniscus that during arthroscopy proved to be rupture of the lateral one calling for a completely different approach. Smillie (1970) also drew attention to this problem. Locking of the knee joint with extension defect was interpreted at the clinical examination as being a sign of rupture of the meniscus. At arthroscopy however no injury of this kind could be found in more than half of the cases. In the present series very few meniscus

In seven cases arthroscopy also disclosed a type of knee injury not previously described: a rupture of the plica synovialis. In the first case the diagnosis was confirmed at operation. It might be argued that the introduction of the arthroscope through the patellar tendon might have caused the injury. The fact that the lesion has never been observed in any of our non acute arthroscopies is evidence against this. The association with a partial rupture of the medial collateral ligament might indicate that the injury represents the initial stage of the rotational force resulting in the unhappy triad.

In conclusion we have found arthroscopy to be a very safe, reliable and useful diagnostic method in cases of acute knee trauma. About two-thirds of the patients had partial third safely avoided. Only three patients were subjected to unsuccessful arthrotomy. No complications occurred.

patients in whom operation could be avoided as a result of arthroscopy and Group II of patients in whom the surgical approach was changed. When the clinical examination was completely in accordance with the arthroscopic diagnosis the arthroscopy was regarded as having been unnecessary (Group III). Patients in whom diagnostic errors, misinterpretations, and technical errors occurred were also referable to groups II-III. Clinical examination at the emergency department gave correct findings in only 15 per cent of cases. Subsequent examination under anaesthesia gave correct findings in only 32 per cent of the patients. In patients with ruptured meniscus the diagnosis was correct in 63 per cent.

Group I Operation avoided (26 cases) In this group, clinical examination on admission, examination under anaesthesia and straight X-ray failed to result in a conclusive diagnosis. In eight patients the knee was locked, simulating rupture of a meniscus. Other patients showed haemarthrosis and a suspected drawer sign forwards, or fractures were present possibly indicating rupture of the anterior cruciate ligament. Four with partial rupture of the anterior cruciate and medial collateral ligaments were included (Table 3).

Group II Change of surgical procedure (31 cases) In this group most patients showed marked haemarthrosis. Ligament injury was suspected but could not be confirmed. Seven of the 10 patients with a rupture of the lateral meniscus were in this group (Table 3). It was often impossible to distinguish clinically between these patients and the patients of group I with haemarthrosis.

Group III Arthroscopy superfluous (27 cases) Here the clinical diagnosis was clear. Of 31 patients with total rupture of the anterior cruciate ligament, 17 were included in this group, as were also 11 out of 17 with ruptured medial

meniscus (Table 3). Many of these patients were referred to us for arthroscopy from other hospitals. An experienced surgeon established the diagnosis by clinical examination, and this was confirmed by arthroscopy.

Complications

No infections occurred. Bacterial cultures of the irrigation fluid before and after arthroscopy were always negative. No adverse effects resulted from flushing with sterile water. In two patients slight pain at the site of introduction of the instrument disappeared after a few weeks. In no case was the field of view obstructed by haemorrhage in the joint even though fresh bleeding sometimes occurred during the procedure.

DISCUSSION

Arthroscopy of an acutely injured knee joint with haemarthrosis presents several difficulties. This is probably why some clinicians regard the condition as a contraindication to the procedure (Casscells 1971, Jackson & Abe 1972, Henche 1974, Glanz 1974). On the other hand early diagnosis of an intra-articular injury has several advantages (Liljedahl & Nordstrand 1969, Gillquist et al 1971, Alm 1974), and efforts to overcome the difficulties will be rewarded. However the haemarthrosis necessitates irrigation of the joint. We have tested several means of doing this (Gillquist & Hagberg 1976). Our present technique using an infusion pump, arthroscopy cannula, and sterile water has proved entirely satisfactory.

Another problem was the new, unfamiliar picture of an acute knee injury. It was sometimes difficult to demonstrate rupture of the anterior cruciate ligament, as the tissue was so fragmented. However, the absence of the

TOTAL HIP REPLACEMENT BY THE BRUNSWIK PROSTHESIS

A Preliminary Report of 189 Operations

T VISURI, P SALENIUS & L E LAURENT

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The results of 189 Brunswick total hip replacements performed at the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland and followed up for 2-3 years are presented. According to the modified system of Merle D'Aubigne & Postel excellent results were achieved in 11.1 per cent (21/189), good in 56.6 per cent (107/189) and fair in 27.5 per cent (52/189). The failure rate was 4.8 per cent (9/189) and consisted of four deep infections, four cases of aseptic loosening and one case of allergic loosening. Local complications occurred after primary operations in 7.5 per cent (12/189) and after revision operations in 26.7 per cent (8/30) and the difference was statistically significant ($P < 0.01$). Among the complications deep infections were encountered in 2.6 per cent (5/189), aseptic loosening in 2.1 per cent (4/189). Other local complications were ectopic ossification in 1.6 per cent (3/189), nerve injuries in 1.6 per cent (3/189), dislocations in 1.1 per cent (2/189) and perioperative fractures in 1.1 per cent (2/189). General complications were observed in 8.9 per cent (17/189). Thromboembolic complications were only seen in 2.6 per cent (5/189). A possible explanation for this low figure was the early ambulation of the patients on the first postoperative day. No deaths related to the operation occurred.

Key words: total hip replacement, metal to metal prosthesis, metal to plastic prosthesis.

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Total hip replacement was first performed at the Orthopaedic Hospital of the Invalid Foundation in 1967 with the McKeel array prosthesis and this prosthesis has been used in a total of 555 hips. Two reports have been published of the results (Langenskiöld & Salenius 1970, Salenius & Laurent 1973). After an increasing number of aseptic loosening of this prosthesis we changed from the metal to metal prosthesis to the metal to plastic prosthesis in December 1972, preferring the Brunswick prosthesis.

The design and size of the Brunswick prosthesis has been described by Lubinus (Lubinus & Jacobsen 1973).

The purpose of this paper is to present the results of the first 189 applications and to analyse the complications of this procedure.

PATIENTS AND METHODS

The patients were operated on between December 1972 and March 1974. The minimum follow up time was 2 years, varying from 20 to 30

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REFERENCES

- Alm, A (1974) Old injuries of the ligaments of the knee joint *Acta chir scand* 140, 283-288
- Alm, A, Gillquist, J & Liljedahl, S-O (1974) The diagnostic value of arthroscopy of the knee joint *Injury* 5, 319-324
- Alm, A & Gillquist, J (1974) Reconstruction of the anterior cruciate ligament by using the medial third of the patellar ligament *Acta chir scand* 140, 289-296
- Brostrom, L, Gillquist, J, Liljedahl, S-O & Lindvall, N (1968) Behandling av invetererad ruptur av framre korsbandet *Svenska Lal-Tidn* 65, 4479-4487
- Casscells, S W (1971) Arthroscopy of the knee joint *J Bone Jt Surg* 53 A, 287-298
- Dandy, D J & Jackson, R W (1975) The impact of arthroscopy on the management of disorders of the knee *J Bone Jt Surg* 57-B, 346-348
- Gallannaugh, S (1973) Arthroscopy of the knee joint *Brit med J* 3, 280-286
- Gillquist, J, Liljedahl, S-O & Lindvall, H (1971) Reconstruction for old rupture of the anterior cruciate ligament A follow-up study *Injury* 2, 271-278
- Gillquist, J & Hagberg, G (1976) A new modification of the technique of arthroscopy of the knee joint *Acta chir scand* 142, 123-130
- Gluz, W (1974) Arthroscopy in trauma of the knee joint *Proceedings of the International Congress Rotterdam, Sept 13-15, 1973* Ed
- Ingwersen, O S *Excerpta Medica, Amsterdam*
- Hienche, H R (1974) Indikation, Technik und Resultate der Arthroskopie nach Traumatisierung des Kniegelenkes *Orthopade* 3, 178-183
- Jackson, R W & Abe, I (1972) The role of arthroscopy in the management of disorders of the knee *J Bone Jt Surg* 54 B, 310-322
- Jackson, R W. (1974) The role of arthroscopy in the management of the arthritic knee *Clin Orthop* 101, 28-35
- Liljedahl, S-O, Lindvall, N & Wetterfors, J (1965) Early diagnosis and treatment of acute ruptures of the anterior cruciate ligament *J Bone Jt Surg* 47-A, 1503-1513
- Liljedahl, S-O & Nordstrand, A (1969) Injuries to the ligaments of the knee Diagnosis and results of operation *Injury* 1, 17-24
- O'Connor, R L (1974) Arthroscopy in the diagnosis and treatment of acute ligament injuries of the knee *J Bone Jt Surg* 56 A, 333-337
- O'Donoghue, D H (1970) *Treatment of injuries to athletes* W B Saunders, London
- O'Donoghue, D H, Frank, G R, Jack, S C & Kenyon, R (1966) Repair of the anterior cruciate ligaments in dogs *J Bone Jt Surg* 48 A, 503-518
- O'Donoghue, D H (1950) Surgical treatment of fresh injuries to the major ligaments of the knee *J Bone Jt Surg* 32 A, 721-733
- Smillie, I S (1970) *Injuries of the knee joint* Livingstone, Edinburgh & London
- Watanabe, M, Takeda, S & Ikeuchi, H (1968) *Atlas of arthroscopy* Igaku Shoin Ltd Tokyo
- Wruhs O (1970) Die Arthroskopie und Endophotographie zur Diagnostik und Dokumentation von Kniegelenksverletzungen *Wien Med Wschr* 8, 126-133

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Key words: total hip replacement, metal-to-metal prosthesis, metal to plastic prosthesis.

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Total hip replacement was first performed at the Orthopaedic Hospital of the Invalid Foundation in 1967 with the McKee-Farrar prosthesis, and this prosthesis has been used in a total of 555 hips. Two reports have been published of the results (Langenskiöld & Salenius 1970, Salenius & Laurent 1973). After an increasing number of aseptic loosening of this prosthesis, we changed from the metal-to-metal prosthesis to the metal-to-plastic prosthesis in December 1972 preferring the Brunswick prosthesis.

The design and size of the Brunswick prosthesis has been described by Lubinus (Lubinus & Jacobsen 1973).

The purpose of this paper is to present the results of the first 189 applications and to analyse the complications of this procedure.

PATIENTS AND METHODS

The patients were operated on between December 1972 and March 1974. The minimum follow-up time was 2 years, varying from 20 to 30

Table 1 Sex and age distribution at operation

Years	20-29	30-39	40-49	50-59	60-69	70-79	80-85	Total
Women	2	0	12	28	68	23	1	134
Men	1	0	5	15	16	9	0	46
Total	3	0	17	43	84	32	1	180

years. The series consisted of 183 patients, but two of them died from causes unrelated to the hip operation and one schizophrenic patient refused to come for follow-up examination. Thus the series consists of 180 patients and 189 hips, nine patients being operated on bilaterally. The age and sex distribution of the patients are given in Table 1. The mean age was 61.9 years. The youngest patient was 25 and the oldest 84 years old. The preoperative diagnoses are listed in Table 2. In 30 patients some kind of hip operation had been performed prior to the arthroplasty (Table 3). This group is called the revision group.

Because of the rather big acetabular component of the Brunswick prostheses which proved to be too large for many female hips, we have used a smaller metal-to-plastic prosthesis, the French Lagrange-Letournel model in such cases (Lagrange & Letournel 1974).

Table 2 Preoperative diagnosis

Primary osteoarthritis	142
Rheumatoid arthritis	11
Posttraumatic arthritis	11
Congenital hip dislocation	6
Old osteomyelitis	4
I egg Perthes' disease	3
Old tuberculous coxitis	1
Slipped epiphysis	1
Post radiation necrosis	1
Total	180

Table 3 Previous operations

Intertrochanteric osteotomy	17
Thompson Austin Moore arthroplasty	4
McKee Farrar arthroplasty	4
Nailing of fracture of the neck of the femur	3
Vitallium cup arthroplasty	1
Skin arthroplasty	1
Total	30

Operation and postoperative care

All patients were operated through an antero-lateral approach according to the technique published by McKee & Farrar in 1966. A post-operative antibiotic prophylaxis started on the first postoperative day was administered to all but 28 patients for 8 days. (Three of the five deep infections occurred among the patients who did not receive antibiotic prophylaxis.) Ampicillin was used in most cases. Prophylactic anticoagulants were not used, only established thromboembolism was treated. The patients were mobilized on the first postoperative day allowing immediate weight bearing. The operations were performed in conventional operating theatres. No air-conditioning or laminar air flow system was available. In high risk patients a preoperative examination by a specialist in internal medicine was carried out. High risk patients were often operated on under hemi-spinal anaesthesia. Statistics concerning operation time, blood loss and anaesthesia are given in Table 4.

RESULTS

The results were evaluated according to a modified system of Merle D'Aubigne & Postel (1954) with six gradations for pain, motion and walking ability.

Pain (Figure 1) 76.7 per cent (138/180) of the patients suffered continuous or intermittent pain at rest before the operation. The relief of pain was marked and 67.7 per cent (122/180) were pain-free after operation. 2.8 per cent (5/180) of the patients still had restrictive pain, in four cases this was due to deep infection and in one case to aseptic loosening. In three other cases of aseptic loosening the pain was tolerable. The average score for pain was 2.36 be

GRADING FOR PAIN

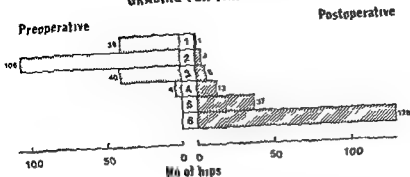


Figure 1 Numerical grading for pain pre and postoperatively in 189 Brunswick total hip replacements

GRADING FOR FUNCTION

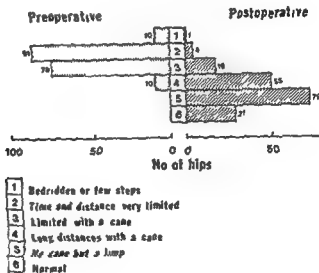


Figure 2 Numerical grading for function pre and postoperatively in 189 Brunswick total hip replacements

fore and 5.40 after the operation with an improvement of 30.1 points

Function (Figure 2) Normal gait was achieved by 17.2 per cent (31/180) of the patients 70.0 per cent (126/180) of the patients had a slight limp or used a cane but could walk long distances. In 12.8 per cent (23/180) the function was limited. The recovery of function was

less marked than the improvement in pain. The improvement rate was on average 2.13 points

Mobility (Figure 3) The recovery of mobility was very similar to that of function with an improvement of 2.24 points. A flexion contracture was present in 30.2 per cent (57/189) of the hips before the operation 5-10° in 23 cases, 10-20° in

GRADING FOR MOBILITY

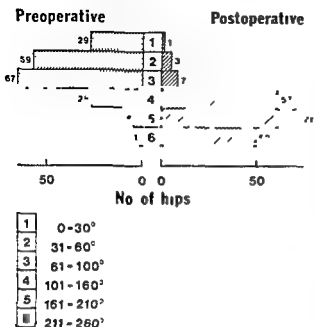


Figure 3 Numerical grading for mobility pre- and postoperatively in 189 Brunswik total hip replacements

11 and 30–40° in 23 cases. Correction of this contracture was obtained in all but four patients. In three of these patients flexion contracture was caused by a massive myositis ossificans and in one a 10° contracture remained.

Overall results (Table 5)

11.1 per cent (21/189) of the hips were classified as excellent: there was no pain, normal gait was achieved and the range of movement of the hip was over 210°.

In 56.6 per cent (107/189) the result was good: i.e., there was no pain, but there was a limp or a cane was needed for long distances. 27.5 per cent (52/189) were classified as fair. The patients had slight or moderate pain and the walking distance was limited. The failure rate was 4.8 per cent (9/189). This group consisted of four cases of deep infection, four cases of aseptic loosening and one case of allergic loosening. The results according to the preoperative diagnosis are given in Table 5.

Complications

General complications These are listed in Table 6. There were very few general complications in this series. No death related to the operation occurred. Deep venous thrombosis developed in four patients postoperatively and pulmonary embolism in one patient 3 weeks after the operation. The diagnosis of thrombosis was based on clinical observation only. The thrombosis was treated by heparin and oral anticoagulants. No late sequelae following thrombosis were observed at the follow-up examination. Cardiac ischaemia was diagnosed in two cases. There were also three cases of postoperative pneumonia. All general infections responded to antibiotic treatment.

Local complications Local complications occurred in 20 patients. Local com-

Table 4 Operation statistics

Surgeons	11
General anaesthesia	146
Hemisplinal anaesthesia	43
Blood loss in primary operation	1360 ml average
Blood loss in revision operation	1430 ml average
Blood loss in hemisplinal anaesthesia	1370 ml average
Blood loss in general anaesthesia	1360 ml average
Blood loss in all operations	1370 ml average
Blood loss from drains	575 ml average
Transfusion total	47 units average
Operation time	110 min average

Table 5 Results according to the system of Merle D'Aubigne

	Primary osteoarthritis	Secondary osteoarthritis	Rheumatoid arthritis	Revision arthroplasty	All hips
Excellent (grading 6-6-6)	19	—	2	—	21 (11 %)
Good (minimal grading 6-4-3)	79	9	7	13	107 (57 %)
Fair (minimal grading 3-3-2)	29	8	3	12	52 (27 %)
Poor (grading under 3-3-2)	2	2	—	5	9 (5 %)
Total	129	19	12	30	189 (100 %)

Table 6 Complications

	Primary operation (159 hips)		Revision operation (30 hips)		All	
	No	Per cent	No	Per cent	No	Per cent
A General						
Deep venous thrombosis	3	1.9	1	3.3	4	2.1
Pulmonary embolism	1	0.6	—	—	1	0.5
Cardiac ischaemia	2	1.3	—	—	2	1.1
Pneumonia atelectasis	3	1.9	1	3.3	4	2.1
Urinary infection	4	2.5	1	3.3	5	2.6
Cholecystitis	1	0.6	—	—	1	0.5
Total	14	8.8	3	10.0	17	8.9
B Local and technical						
Deep infection	2	1.3	3	10.0	5	2.6
Aseptic loosening	1	0.6	3	10.0	4	2.1
Myositis ossificans	3	1.9	—	—	3	1.6
Nerve damage	3	1.9	—	—	3	1.6
Dislocations	2	1.3	—	—	2	1.1
Peroperative fractures	—	—	2	6.7	2	1.1
Loose cement bodies	1	0.6	—	—	1	0.5
Total	12	7.5	8	26.7	20	10.6

plications were seen in 12 patients after primary operation and in 8 patients after revision operation. This difference is statistically significant ($P < 0.01$).

There were five deep infections in this series. The course and treatment, and

the bacteria of the infected hips, are given in Table 7.

Three of the four aseptic loosening were caused by malpositioning of the prosthesis. One case of allergic loosening, proved by a skin sensitivity test, was

GRADING FOR MOBILITY

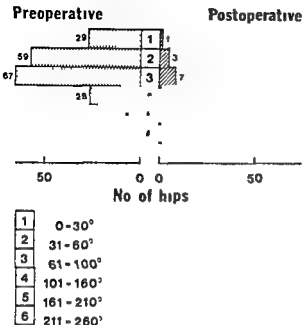


Figure 3 Numerical grading for mobility pre- and postoperatively in 189 Drunsil total hip replacements

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of infections

Time of infection	Appearance of infection	Treatment	Final result
Early	Sinus	Debridement irrigation	Good
Early	Sinus	Debridement irrigation	Girdlestone
	loosening of femoral part	reapplication of femoral part, removal of prosthesis	
Early	Loosening of femoral part	Reapplication of femoral part	Good
Late 4 months	Loosening of both parts	Removal of prosthesis	Girdlestone
Late 5 months	Sinus	Debridement irrigation	Girdlestone
	loosening of both parts	removal of prosthesis	

postoperative complications particularly thromboembolism is early mobilization of the patient. The rate of thromboembolic complications in our series was 2.6 per cent without the use of anti-coagulants. This low figure is comparable to the incidence of thromboembolic complications in patients treated prophylactically with dextran 40 or sodium warfarin (Evaris 1974; Beckenbaugh et al 1974).

It is difficult to compare the results of total hip replacement reported by different authors because the systems of evaluation vary. It is more reliable to compare the number of failures. In our series the local failure rate was 4.8 per cent and in Lubinus series 3.7 per cent (Lubinus 1973). The results of Brunswick operations are highly satisfactory and we intend to continue using the Brunswick prosthesis.

ACKNOWLEDGMENT

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REFERENCES

- Beckenbaugh R B, Coventry M B & Nolan D R (1974) Prophylactic anticoagulation with sodium warfarin in total hip arthroplasty. In *Proceedings of the Second Open Scientific Meeting of the Hip Society* pp 190-194. C V Mosby Company, St Louis.
- Coventry M B, Beckenbaugh R D, Nolan D R & Ilstrup M S (1973) 2012 total hip arthroplasties. A study of postoperative course and early complications. *J Bone Jt Surg* 56 A 273-284.
- D'Aubigne R M & Postel M (1964) Functional results of hip arthroplasty with acrylic prosthesis. *J Bone Jt Surg* 36 A 451-475.
- Evaris C M (1974) Prevention of thromboembolism by use of low molecular weight dextran. In *Proceedings of the Second Open Scientific Meeting of the Hip Society* pp 182-190. The C V Mosby Company, St Louis.
- Ilstrup M S, Nolan D R, Beckenbaugh R D & Vernon Roberts H (1973) Factors influencing the results in 2012 total hip arthroplasties. *Clin Orthop* 95 250-262.
- Lagrange J & Latourneil M (1975) The "L.L." total hip prosthesis. *Int Surg* 60 21-24.
- Langenskiöld A & Salenius P (1970) Total replacement of the hip by McKee Farrar prosthesis. A preliminary report of 81 cases. *Clin Orthop* 72 104-105.
- Lubinus H (1973) Total hip replacement using Brunswick system. *Clin Orthop* 95 211-212.
- Lubinus H & Jacobsen U (1973) Erfahrungen mit dem totalen Hüftersatz unter Verwendung des systems Brunswick und eines dorso-lateralen Zugangs. In *Der Total-Hüftgelenk-ersatz* pp 97-107. Ed Cotta H & Schulitz, H P. Georg Thieme Verlag Stuttgart.
- McKee G A & Watson Farrar J (1966) Replacement of arthritic hips by the McKee Farrar prosthesis. *J Bone Jt Surg* 48 B 245-259.
- Salenius P & Laurent L E (1973) Experience with the McKee Farrar total hip replacement. *Acta orthop scand* 44 451-459.

Table 7 The course

Patient	Previous operation	Prophylactic antibiotic	Bacterium
AR	None	None	Staphylococcus aureus
VM	Displacement osteotomy	None	Pseudomonas
FP	Displacement osteotomy	Ampicillin	Staphylococcus aureus
IS	None	None	Staphylococcus epidermidis
AH	McKee-Farrar total hip prosthesis	Cloxacillin	Staphylococcus aureus

seen after reapplication of a loosened McKee-Farrar prosthesis. Two peroperative fractures occurred. In three cases a massive heterotopic ossification developed causing stiffness of the hip. Three cases of peroperative nerve damage occurred. There were two injuries to the femoral nerve, one recovered completely, the other seems to be permanent. There was one sciatic nerve injury, which was due to a posterior dislocation of the femoral part of the prosthesis. This palsy has partly disappeared. Dislocations occurred in two patients. One was caused by a fall. The other was due to a too vertical insertion of the acetabular part.

DISCUSSION

We have encountered some difficulties with both the acetabular and the femoral parts of the Brunswik prosthesis. Because of its large size the Brunswik socket is easily inserted in a too vertical position. It fits the acetabulum best in a vertical position. Two complications resulted from this vertical insertion of the socket, one dislocation and one loosening of the cup. On the other hand, the big socket has proved very suitable in cases of deep acetabular protrusion, as is often seen in rheumatoid arthritis.

We have also encountered difficulties in the positioning of the standard femoral parts in femora osteotomized earlier. Three local complications (2 loosening

and 1 fracture) accompanied these difficulties. It is evident that a specially designed straight stem is necessary in such cases.

If one compares the local complications of our McKee-Farrar series after 3 years observation (Silenius & Laurent 1973) with those of the Brunswik operations, there are two differences. One is a decrease in the rate of deep infections from 4.8 per cent to 2.6 per cent. This difference may be explained by the use of systemic antibiotic prophylaxis, because the other conditions remained the same. The most marked difference between the operations is, however, a decrease in aseptic loosening. The incidence of aseptic loosening in the McKee-Farrar series was 12 per cent (18/143) six times higher than that in the Brunswik series (2.1 per cent). After 6-7 years follow-up this figure has doubled. We do not expect such a high incidence of aseptic loosening in our Brunswik series. This difference justified the change from an all-cobalt chrome prosthesis to a metal-to-plastic prosthesis.

The frequency of general complications in large series of hip arthroplasties has been reported to be 13-25 per cent (Ilstrup et al 1973, Coventry et al 1975). Lubinus reports a frequency of 15 per cent (Lubinus & Jacobsen 1973). In our series the frequency was 8.0 per cent with no death related to the operation. The most important factor preventing

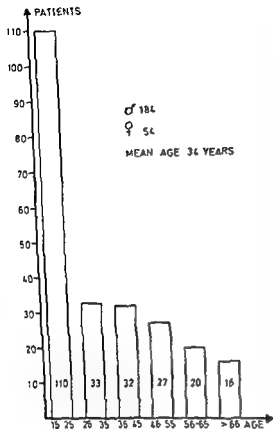


Figure 1 Age distribution of 238 patients with tibial shaft fractures

(Muller et al 1963, 1970) have been widely accepted in a number of European countries and the USA, relatively few papers have been published on the results of compression osteosynthesis in fractures of the tibial shaft (Infanger et al 1971, Olerud & Karlström 1972, Röed et al 1976, Solheim 1973, Smith 1974).

We therefore consider it of interest to compare the results of treatment with AO plates, conventional Eggers or Lane plates and conservative treatment.

PATIENTS AND METHODS

During the period July 1966 to April 1973 238 patients over the age of 15 with tibial shaft fractures, were treated as inpatients at the

Department of Orthopaedic Surgery, Frederiksberg County Hospital, Hillerød, Denmark. The age distribution is shown in Figure 1.

The tibial shaft was defined as the area from 7 cm below the knee joint to 7 cm above the ankle joint. Table 1 compares the type of fracture and the cause of injury and it can be seen that the majority of comminuted and transverse fractures were caused by high velocity traumas. Multiple injuries including other severe fractures or body injuries were found in 55 patients.

Thirty nine per cent were open fractures (93/238) and could be classified as follows: *Grade I* simple skin perforation from within, *Grade II* skin perforation from without including minor skin or muscle contusion, *Grade III* extensive soft tissue damage with major loss of skin sometimes associated with lesions of vessels or nerves. Table 2 lists the open fractures according to the cause of injury, 74 out of 93 open fractures (80 per cent) were due to traffic accidents. The method of treatment is correlated to the cause of injury in Table 3 and to the type of fracture in Table 4. Thirty-one patients were treated with "other operative methods", including interfragmentary compression with lag screws in 16 cases, medullary nailing in 5, Rush-pinning in 4, cerclage wires in 3 and external fixation with Hoffmann apparatus in 2 cases. In one case a primary above knee amputation was performed. This group of patients have been excluded from the follow up, because the intention was to compare only conservative treatment and the two types of plate osteosynthesis.

The standard treatment of fractures of the tibial shaft has been conservative with closed reduction and immobilization in a high plaster cast. If conservative treatment did not lead to stable reduction with anatomical alignment, osteosynthesis was performed within the first 48 hours after admission. In the period 1966 to 1970, plate osteosynthesis was performed with open reduction and fixation of the fracture with conventional Eggers or Lane plates, followed by immobilization in a high plaster cast. Since 1970, AO compression plates have been used with open reduction and application of interfragmentary compression with lag screws combined with neutralization plates, or axial compression plates of the AO type (Muller et al 1970). In these cases no cast was applied and immediate training for joint mobility was started, followed by early non weight bearing mobilization. Full weight bearing was allowed in all groups when the fracture was considered united and normal muscle and joint function had been obtained.

All tibial shaft fractures whether open or closed have been treated according to these

TIBIAL SHAFT FRACTURES

A Comparison of Conservative Treatment and Internal Fixation with Conventional Plates or AO Compression Plates

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Department of Orthopaedic Surgery, Frederiksborg County Hospital, Hillerød, Denmark

Out of a series of 207 consecutive fractures of the tibial shaft 102 were treated conservatively. 64 fractures were treated by AO compression plate osteosynthesis and 41 by internal fixation using Eggers or Lane plates. The choice of method was independent of the extent of soft tissue damage. A follow up examination of 199 fractures with a mean observation time of 3.4 years revealed residual malalignment in 21 per cent of conservatively treated cases and in 8 per cent after conventional plate fixation while the AO method resulted in anatomical restoration of the axis of the tibia in all cases. However removal of the compression plates was followed by re fractures early and late in 11 per cent. Implant failure occurred in 5 per cent of both types of plate fixation and 3 per cent of the conservatively treated cases redislocated. Infection developed in 5 per cent of closed fractures and in 11 per cent of open fractures treated by operative means. Of the conservatively treated cases only 3 per cent of the open fractures developed infection. The risk of infection following acute internal fixation is thus four times greater than with conservative treatment. AO compression plate fixation shortened the time of fracture healing considerably. The rate of non union after conservative treatment was 6 per cent in closed and 21 per cent in open fractures. Similarly in conventional plate fixation there was non union in 8 and 24 per cent respectively. Non union was not encountered after AO compression plate osteosynthesis. It is concluded that AO plate osteosynthesis is justified in the treatment of open tibial shaft fractures and also useful in closed fractures when conservative treatment does not lead to stable reduction with a good alignment.

Key words: tibial shaft fractures, osteosynthesis, infection, osteosynthesis, non union, internal fixation, AO compression, osteosynthesis, Eggers plates, Lane plates.

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The ideal treatment for tibial shaft fractures is still a controversy. The problems involved have been thoroughly described

This study was supported by a grant from Frederiksborg County Hospital in Hillerød, Denmark.

in a whole volume of *Clinical Orthopaedics and Related Research* (Clin Orthop 105 1974) edited by A. Sarmiento with contributions from several authors with solid experience in this field. Although the principles of the AO group

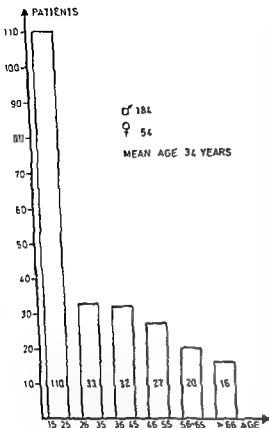


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Thirty nine per cent were open fractures (93/238) and could be classified as follows Grade I simple skin perforation from within Grade II skin perforation from without including minor skin or muscle contusion Grade III extensive soft tissue damage with major loss of skin sometimes associated with lesions of vessels or nerves Table 2 lists the open fractures according to the cause of injury 74 out of 93

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PATIENTS AND METHODS

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Table 1 Type of fracture/cause of injury

	Traffic accident	Fall	Work accident	Sports injury
Oblique fracture	34	35	9	11
Transverse fracture	39	1	2	21
Comminuted fracture	67	6	4	9

Table 2 Cause of injury/extent of soft tissue damage

	Total no	Grade I	Open fractures Grade II	Grade III	Total
Traffic accident	140	26	37	11	74
Fall	42	7	1		8
Work accident	15	1	3	1	5
Sports injury	41	2	4		6
Total no	238	36	45	12	93

Table 3 Cause of injury/method of treatment

	Conservative treatment	Operative treatment AO plates	Eggers/Lane plates	Other methods
Traffic accident	60	39	28	13
Fall	15	12	4	11
Work accident	6	4	2	3
Sports injury	21	9	7	4
Total no	102	64	41	31

Table 4 Type of fracture/method of treatment

	Conservative treatment	Operative treatment AO plates	Eggers/Lane plates	Other methods
Oblique fracture	32	27	9	19
Transverse fracture	37	8	14	4
Comminuted fracture	33	29	18	8
Total no	102	64	41	31

principles. In open fractures systemic antibiotics were administered routinely.

A clinical and roentgenological follow up study of the knee, the ankle and the entire tibial shaft in two planes was performed in

199 of the 207 patients treated according to these principles after a mean observation time of 3.4 years (Figure 2). Three patients died during hospitalization and five patients were lost to follow up.

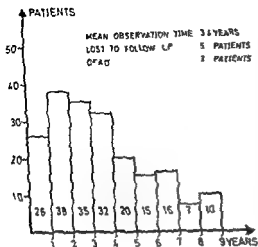


Figure 2 Period of observation at follow-up of 199 patients

Table 5 General complications among 207 patients

	Conservative treatment	Operative treatment
Cardio pulmonary	2*	2
Pulmonary embolism		2*
Fat embolism	4	4
Phlebo thrombosis	1	1
Peroneal palsy	2	2
Total no.	9	11
Died in hospital	1	2

Fatal complications in 3 patients

RESULTS

General complications (Table 5) were encountered in 10 per cent of the patients (20/207). There was no difference between the conservative and operative group. There were eight patients with fat embolism, seven had femoral shaft fractures and one multiple injuries. Three patients died in hospital, in two cases the cause was pulmonary embolism and in one case it was cardiopulmonary complications.

Local complications were encountered in 30 per cent of the patients (61/207). Dislocation following conservative treatment was seen in 3 per cent (3/102) leading to secondary osteosynthesis. Implant failure occurred in three cases after AO plate osteosynthesis and in two cases after conventional plate fixation—a total of 5 per cent (5/105). This was due to metal fatigue secondary to instability caused by a bone defect opposite the plate.

In Tables 6-8 the problems concerning infection and non union are presented. It should be noted that the tables include three cases of above-knee amputation. All these were severe Grade III fractures, in which a rather heroic attempt had been made to save the limb. Two of the amputations were preceded by severe skin necrosis and one by deep infection.

Table 6 Local complications following conservative treatment

	Closed fractures	Grade I	Open fractures		Total	Total no of complications
			Grade II	Grade III		
No. of patients	11	32	23	4	38	
Skin necrosis or superficial infection	1	3	8	2	13	14
Osteitis	6			3	1	1
Non union	4	2	5	1	8	12
Amputations	0			1	1	1
Total no	5	4	11	2	18	23

Table 7 Local complications following AO-compression osteosynthesis

	Closed fractures	Grade I	Open fractures Grade II	Grade III	Total	Total no of complications
No of patients	37	16	7	4	27	
Skin necrosis or superficial infection	2	1	3	3	7	9
Deep infection	1	1	1	1	3	4
Osteitis	1				0	1
Amputation	0			2	2	2
Total no	4	2	4	6	11	13

Table 8 Local complications following conventional plate osteosynthesis

	Closed fractures	Grade I	Open fractures Grade II	Grade III	Total	Total no of complications
No of patients	24	6	9	2	17	
Skin necrosis or superficial infection	3	1	3	2	6	9
Deep infection	0		1		1	1
Osteitis	1		1		1	2
Non union	2		4		4	6
Total no	6	1	8	2	11	17

Table 9 Results of follow up of 199 patients

	Conservative treatment	AO compression plates	Fingers/1 and plates
Patients treated	102	64	41
Patients followed up	100	61	39
<i>Röntgenological findings</i>			
Shortening ≥ 2 cm	5	0	0
Malalignment *	21	0	3
<i>Clinical findings</i>			
Ankle joint motion reduced $\geq 20^\circ$	7	3	0
Pain/weather sensitivity	7	3	2
Knee/ankle complaints	5	1	3
Re-fracture	1	1	0
Total no **	41	11	8

* Malalignment valgus/varus-angulation $\geq 8^\circ$ and/or curvature $\geq 15^\circ$

** Some patients had more than one complaint or objective finding

- CONSERVATIVE TREATMENT — 37 PATIENTS
 — AO COMPRESSION PLATES — 8
 — EGGERS/LANE-PLATES — 14

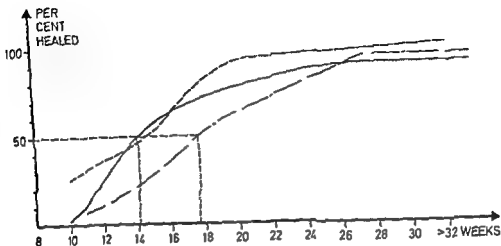


Figure 3 Healing time for transverse fractures

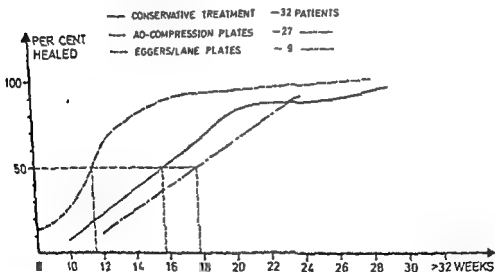


Figure 4 Healing time for oblique fractures

As seen in Table 6 nearly all skin necrosis and infections, following conservative treatment, occurred among the open fractures. Non union was encountered in 6 per cent (4/61) of closed

fractures and in 21 per cent (8/38) of open fractures, but three of the latter were preceded by skin necrosis.

The local complications following AO osteosynthesis are listed in Table 7. In 27

- CONSERVATIVE TREATMENT —33 PATIENTS
 - - - AO-COMPRESSION-PLATES —29 —
 - - - EGGERS/LANE-PLATES —18 —

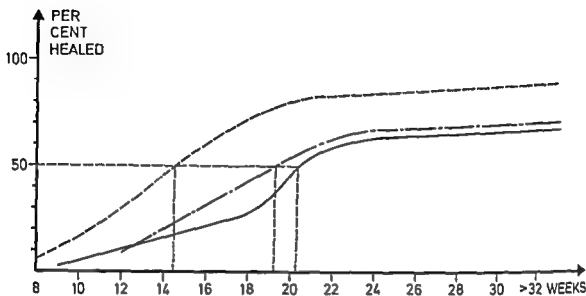


Figure 5 Healing time for comminuted fractures

open fractures there were two late deep infections, both of which healed after removal of the implant. The third deep infection was the one mentioned leading to amputation, giving a total infection rate of 11 per cent (3/27). In 37 closed fractures the osteosynthesis was followed by one deep infection and one osteitis, both of which healed after 8 weeks and 13 months, respectively. The infection rate for closed fractures was thus 5 per cent (2/37). Non-union was not encountered after AO compression osteosynthesis.

In Table 8 it can be seen that local complications occurred in 11 out of 17 open fractures treated with conventional plates. The infection rate was 12 per cent (2/17) and both healed. The frequency of non-union was 24 per cent (4/17). In 24 closed fractures one late osteitis (4 per cent) was encountered, and two cases of non-union (8 per cent).

Fracture healing time The radiological criteria for union in conservative treat-

ment and conventional plate osteosynthesis was solid, bony bridging of the fracture line by periosteal and endosteal callus. Because of the so-called primary fracture healing obtained by the compression type of osteosynthesis it is difficult to define exactly when bony union has occurred. We have considered these fractures as healed when the fracture line was invisible between the 8th and the 16th week provided there was no formation of irritation callus, or if irritation callus which had appeared earlier had been transformed into solid fixation callus. As the different types of fractures do not involve similar problems of union we have illustrated the cumulative healing time for each group separately.

The majority of the transverse fractures (Figure 3) were treated conservatively and healing was obtained for 50 per cent of the fractures within 14 weeks. This was 3 weeks shorter than with conventional plate fixation. In oblique fractures (Figure 4) the healing time for

50 per cent of the fractures was 4 weeks shorter in the case of compression osteosynthesis compared with conservative treatment. The healing time for comminuted fractures (Figure 5) was markedly prolonged. Fifty per cent were healed 11 weeks earlier in the AO group compared to the other two groups.

Results of the follow up study are listed in Table 9. The roentgenological examination showed malalignment in 21 per cent (21/100) after conservative treatment and in 8 per cent (3/38) after conventional plate fixation. The axis was restored in all cases after AO osteosynthesis.

Pain was present in 12 patients, but in six cases this was only slight discomfort related to changes in the weather.

Re fracture was observed in 1 per cent (1/100) after conservative treatment and in 11 per cent (5/46) after AO compression osteosynthesis. The implant had been removed from 46 of the 61 patients attending the follow-up.

A total of 30 per cent of the patients (60/109) presented with complaints or objective findings. However, half of this number were patients treated for comminuted fractures.

DISCUSSION

The difficult problem in the treatment of tibial fractures is whether to operate and risk infection, which can follow any form of operation. Following conservative treatment of 61 closed fractures there were no severe infections, deep infection developed in 5 per cent of 61 patients treated with internal plate fixation. Among 34 cases of open fracture there was one deep infection following conservative treatment, whereas 11 per cent of 11 patients treated by internal fixation developed deep infection. These infection rates are similar to those reported in other comparable series of closed fractures (Infanger et al 1970, Karlström &

Olerud 1974, Olerud & Karlström 1972, Rüttmann et al 1970, Rüedi et al 1976). As for open fractures, however, our figures, like Rüedi et al's (1976), are lower than those presented by others (Bauer & Hulth 1973, Smith 1974). Primary open fracture treatment undertaken as an early acute procedure increased the risk of infection four-fold, but all these infections eventually healed and the fractures united, although the course was prolonged. According to Aho & Hakkarainen (1974) and Smith (1974) the infection rates may be reduced considerably if the internal fixation is delayed for 2-3 weeks in open as well as in closed fractures.

Concerning the problems of fracture union we found that transverse fractures united fairly rapidly with conservative treatment. Oblique and comminuted fractures showed a prolonged healing course as has been pointed out by Nicoll (1974). Considerable time was gained, however, by the use of compression osteosynthesis, while with conventional plate osteosynthesis the healing time was the same as with conservative treatment. There was no non-union after AO compression osteosynthesis, whereas with conservative treatment there was 6 per cent non-union in closed fractures and 21 per cent in open fractures. Conventional plate fixation involved 8 per cent non union in closed fractures and 21 per cent in open fractures. The literature contains only a few papers concerning this problem. Smith (1974) reported 30 per cent with delayed union (≥ 26 weeks) after primary internal fixation of closed fractures and 48 per cent in open fractures, but again these figures were considerably reduced when using delayed osteosynthesis. Rüedi et al (1976), however, found 4 per cent with delayed union in closed fractures and 13 per cent in open fractures applying the dynamic compression plate (DCP).

In our series 3 per cent implant failures

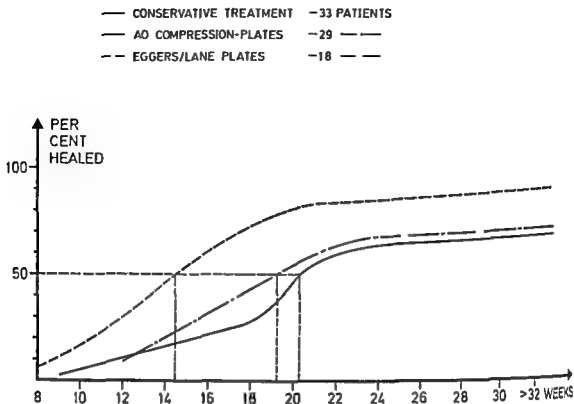


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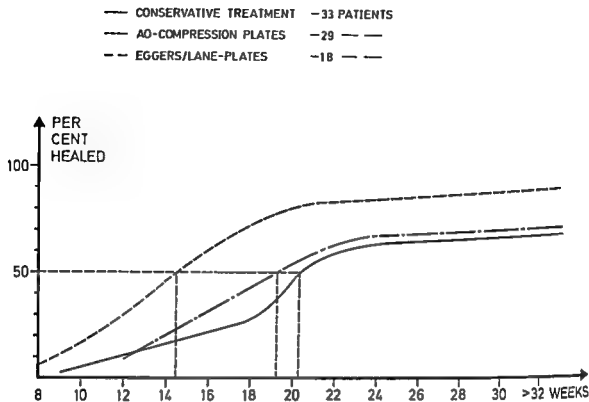


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PROCEEDINGS OF THE SCANDINAVIAN ORTHOPAEDIC SOCIETY

38th Assembly

Oslo Norway, June 1976

LUMBAR RADICULOGRAPHY WITH METRIZAMIDE ("AMIPAQUE") I O Skolpe Oslo Norway

Amipaque is a non ionic water soluble contrast medium for use in the subarachnoid space. The toxicity is lower than for other commercially available contrast agents. It can be injected without spinal anesthesia and gives good radiological contrast with an iodine concentration isotonic with the cerebral spinal fluid (170 mg I/ml). Serious acute complications have not been reported after more than 20 000 examinations. Late sequelae such as adhesive arachnoiditis have not been seen. The spasmogenic effect of the medium is very low and therefore the conus region can be included in the examination. For the same reason functional myelography can be carried out in cases of suspected lumbar spinal stenosis.

PROGNOSIS OF 153 SCIATICA PATIENTS Antti Ilho Erkki Karaharju Timo Paasilainen & Erkki Paananen Helsinki Finland

The patients were admitted to the hospital for symptoms and signs of sciatica. Fifteen patients were operated on for cauda equina syndrome. In elective disc operation was performed on 116 patients. Minimum length of history 2 months average 46 months. A disc herniation was found in 104 operations (five false negative myelograms). No protrusion or other cause of nerve root compression was found in eight cases. Four false positive myelograms. Compared with a series 10 years earlier the frequency of operation on two disc spaces had diminished from 30 per cent to 15 per cent and the frequency of unsatisfactory operative findings from 15 to 7 per cent. This we consider to be due to an improved myelographic technique and a better selection of patients for surgery. Postoperatively the frequency of radiating pain was

58 per cent at 3 months 12 per cent at 6 months and 20 per cent at 12 months. When the clinical radiological and operative findings were correlated with the results a positive correlation was found only between an adequate operative finding and a good result. Conservative treatment was chosen in 27 cases where the clinical and radiological findings were not conclusive or when the patient refused to undergo an operation. One year later there were no significant neurological differences between this group and the group which had undergone surgery. In our earlier series we observed that the prognosis for 5 to 10 years did not depend on the operative result. We conclude that in spite of 40 years' experience and intensive research including the cognizance of spinal stenosis and improvements in myelography the enigma of sciatica has only partially been solved.

INDICATIONS FOR ACUTE SURGERY IN HERNIATED LUMBAR DISC Georg Blaker Oslo Norway

Recovery after compression of nervous structures depends on the acuteness degree and duration of the compression. Hence patients with acute lower limb or urinary bladder paresis due to herniated lumbar disc are operated upon as soon as possible after emergency myelography.

With earlier types of water soluble contrast media operation was postponed for 6 hours. After the introduction of metrizamide surgery has been performed immediately after the X-ray examination without adverse reactions.

Several patients were admitted to our department at varying times after onset. In a series of 107 patients with discogenic acute back pain patients had surgery within 43 hours of onset and 26 in the next 43 hours. In 31 patients there was a delay of more than one week.

33 patients operated upon within 24 hours of onset and the majority operated within the

were seen in both types of plates, which agrees well with the findings of Olerud & Karlstrom (1972), but this figure is slightly higher than that stated by Ruedi et al (1976). The implant failures were however all due to metal fatigue because of instability caused by gaps in the fracture line opposite the plate. The number of failures did not exceed our frequency of secondary displacements after conservative treatment.

Malalignment leads to changes in the load distribution of the joint surface and late development of osteoarthritis may result. One of the aims of osteosynthesis is therefore anatomical alignment. Twenty-one per cent of the fractures were malaligned following conservative treatment and 8 per cent after conventional plate fixation. After AO plate fixation anatomical alignment was achieved in all cases.

Removal of the AO plates 1 year after application was followed by 11 per cent re-fractures. This is about three times as many re-fractures as are stated by Olerud & Karlstrom (1972) and more than twenty times the figures of Ruedi et al (1976). Nearly all re-fractures were caused by new relevant traumas during sporting activities, such as soccer. Three of the re-fractures occurred after 1-2 years, the remaining two occurred within 2 months of implant removal.

In conclusion, we find that AO compression osteosynthesis is justified in the treatment of open tibial shaft fractures and is also a useful tool in cases of closed fractures, because of anatomical reduction, safe union and a shorter healing time in spite of an increased infection rate. This disadvantage might be overcome by delayed osteosynthesis and by application of the plate on the lateral aspect of the tibial shaft covered by muscles. As mentioned by others, however, (Bauer & Hulth 1973, Karlstrom & Olerud 1973, Wade 1970) the AO method

may be a dangerous tool, and we feel that the use of this method must be restricted to experienced orthopaedic surgeons. In our series of patients osteosynthesis with conventional Eggers or Lane plates was not superior to conservative treatment, which is still the method of choice whenever it is possible to retain reduction and good alignment.

REFERENCES

- Aho, A. J. & Hakkarainen, M. (1974) Closed leg fractures. *Acta chir scand* 140 457-465.
- Bauer, G. & Hulth, A. (1973) Kompressionsosteosynthesen enligt AO vid underbenets distals frakturter b6r overges. *Svensk Lak Tidn* 70 4752-4753.
- Infanger, K., Fennner, A., Cadalbert, M. & Schmaun, M. (1971) Ergebnisse der operativen Behandlung der Unterschenkel Schaftfrakturen anhand von 230 Fallen. *Helv chir Acta* 3 311-316.
- Karlstrom, G. & Olerud, S. (1973) Har stabil plattosteosyntes av tibiafrakturer n6got ber6ttigande? *Svensk Lak Tidn* 70 4754-4755.
- Karlstrom, G. & Olerud, S. (1974) Fractures of the tibial shaft. *Clin Orthop* 105 82-115.
- Muller, M. F., Allgower, M. & Willenegger, H. (1963) *Operative Fracturenbehandlung*. Springer, Berlin, Gottingen, Heidelberg.
- Muller, M. F., Allgower, M. & Willenegger, H. (1970) *Manual of internal fixation*. Springer, Berlin, Heidelberg, New York.
- Nicoll, L. A. (1974) Closed and open management of tibial fractures. *Clin Orthop* 103 144-153.
- Olerud, S. & Karlstrom, G. (1972) Tibial fractures treated by AO compression osteosynthesis. *Acta orthop scand* Suppl 140.
- Rittmann, W. W., Matter, P. & Allgower, M. (1970) Behandlung offener Frakturen und Infektionshaufgkeit. *Acta chir Austr* 2 10-21.
- Ruedi, T., Webb, J. K. & Allgower, M. (1976) Experience with the dynamic compression plate (DCP) in 418 recent fractures of the tibial shaft. *Injury* 7 252-257.
- Smith, J. F. M. (1974) Results of early and delayed internal fixation for tibial shaft fractures. *J Bone Jt Surg* 56 B 469-477.
- Solheim, K. (1973) Tibial fractures treated according to the AO method. *Injury* 4 213-220.
- Wade, P. A. (1970) ASIF compression has a problem. *J Trauma* 10 513-515.

herniation. There were 10 girls and 16 boys. The duration of symptoms was on average 20 months before diagnosis was made. Only 10 patients were referred to the hospital under the diagnosis of ischialgia. A previous trauma was found in nine cases.

Subjective symptoms were mild. Common objective findings were scoliosis, kyphosis and back stiffness. Changes in gait pattern were frequent. Lasègue's test was positive at a few degrees. Peripheral neurological signs were nearly always absent. Our clinical material indicates there is a difference in symptomatology of lumbar disc herniation in children and adolescents as compared to adults.

Mean follow up was 5.8 years. Operative results were judged as excellent in 29 cases, fair in 7. Scoliosis disappeared in all patients.

FINDINGS AND RESULTS AFTER RE-OPERATION FOR LUMBAR DISC PROLAPSE 4. Vedsted Oslo, Norway

Eighty five out of 104 patients re-operated upon for lumbar disc prolapse replied to a questionnaire. Perioperative findings at re-operation were: prolapse in the same disc in 33 patients, prolapse in another disc in 16 patients, prolapse and perineural scarring in 10 patients and perineural scarring and/or bony excrescences in 31 patients. Results were stated as excellent by 31 patients, good by 29 patients and poor by 25 patients. True recurrences had very good results but 11 in addition marked perineural scarring was found a little less than 50 per cent benefitted from the re-operation. The same was true if at operation only perineural scarring and/or bony excrescences was found. Myelography before re-operation gave positive or correct information in 63 per cent of cases. Age and method of exposure did not seem to be of any significance. The few backs with multiple operations had almost the same results as the others.

PROLAPSED LUMBAR INTERVERTEBRAL DISC: A 10 YEAR POSTOPERATIVE FOLLOW UP

Flemming F. Madsen, Erik Th. Kjeldbye &
Elin Fuglstad
Sonderborg, Denmark

A total of 174 patients were followed for variable periods up to 10 years and evaluated by questionnaire. The operation was hemilaminectomy and evacuation of hernia and the inter-corporal space. No fixation was performed.

Mean age was 39.9 years and the female to male ratio was 1:2.

At the 10 year follow-up (96 patients), 56 per cent had regained full working capacity and had no symptoms or only mild ones, 21 per cent had full working capacity but had some back symptoms and 27 per cent had a considerably lowered working capacity and/or major back complaints.

The following factors correlated with a good prognosis: age less than 40 years, no previous back complaints, short duration of symptoms at operation, preoperative work that was not back-straining, and high social position. A positive correlation was found between high social position and no back strain at work. Preoperative back strain at work had a minimal influence on the results, whereas social position was the most important factor.

Two to ten years postoperatively, the condition of the patients had changed only to a slight degree, the number of patients deteriorating slightly exceeding the number of patients improving. The postoperative symptoms of the individual patients were thus very stable after 2 years.

RESULTS IN PATIENTS

RESULTS IN PATIENTS

A follow-up study was made on 544 patients operated on, between 1962 and 1972, for herniated disc with removal of one or more discs. 38 per cent were women, 64 per cent were men. The average age at the time of operation was 40.3 years. The follow up period was from 4-14 years, in average 8.4 years.

The history was acute in 25 per cent of the cases. Work was a direct causative factor in 40 per cent of the cases.

About half of the patients sought non medical treatment (quack doctors or chiropractors) before hospitalization, which consequently was delayed. The results were better in the cases where the patients were operated upon within the first 2 months of the onset of symptoms, and they were better in younger than in older patients. There was a correlation between the myelography and the findings at operation in 91 per cent of the cases. There were only a few complications of myelographies and operations and no mortality. 22 per cent were operated upon without delay. 75 per cent of the cases gained relief from pains in the back and the legs. The number with pareses was significantly reduced, but the number with disturbances of sensibility and reflexes was not reduced in the

next 24 hours, regained normal function. The recovery rate then decreased steeply. Although all patients benefitted from surgery, incomplete recovery was the rule when there was a delay of more than one week.

UNILATERAL AND BILATERAL ARCOTOMY FOR LUMBAR DISC PROLAPSE WITH UNILATERAL SCIATICA: A FOLLOW-UP STUDY OF 156 PATIENTS

Rolf Hagen & Ivar B. Engesæter
Sandvika, Norway

The best surgical approach for lumbar disc lesions is still open to discussion, and few comparative reports have been published.

Out of 250 patients operated upon for lumbar disc lesions between 1967-71, 156 were selected for review according to the following criteria: a) at least 6 months preoperative history, b) unilateral sciatica, c) L 4-5 or L 5-S 1 disc lesion, d) no previous disc operation.

Bilateral arcotomies were performed on 67 patients (Group I) and unilateral arcotomy on 89 (Group II). The follow-up was made 4-9 years postoperatively, and the patients in both groups were of similar age, sex and occupation. They had similar histories, symptoms and signs, and myelographic findings. No patient in Group I needed reoperation for recurrent prolapse whereas further surgery was required in four from Group II. At follow-up, 43 were symptom-free and 24 improved in Group I, while 30 were symptom free, 44 improved, 2 unchanged and 12 worse in Group II. During the follow-up period 13 per cent of patients in Group I and 26 per cent in Group II had severe attacks of sciatica. At the time of follow up 30 per cent in Group I and 51 per cent in Group II had low back pain.

Bilateral arcotomy proved to be the operation of choice. It caused no instability and did not predispose to the formation of adhesions opposite the lesion.

COMPARISON OF THE RESULTS IN PATIENTS OPERATED UPON FOR RUPTURED LUMBAR DISCS WITH AND WITHOUT SPINAL FUSION

Nils Eie
Oslo, Norway

From 1967-1969 simple extirpation of the ruptured disc and excocleation of the intervertebral space were performed in 191 patients, whereas a combined extirpation and lumbosacral fusion according to a modified Smith-Petersen's method, was performed in 94 patients.

Follow up studies in 1974-1975 showed that during the first half postoperative year the results were similar in the two groups with a satisfactory result in 89 per cent of the patients

without spinal fusion and in 83 per cent of the patients with fusion. Pain reappeared later in 26 per cent of the patients without fusion and in only 14 per cent of the patients with the combined operation. Nineteen patients or 10 per cent of the patients without spinal fusion were reoperated upon for recurrence or another ruptured disc. One was operated upon for extradural scar formation and adhesions, 11 had further courses in physiotherapy. Recurrence of a disc protrusion in the area of a solid fusion has not been observed. Two patients with fusion had reoperations for pseudarthrosis in the graft and one for a ruptured disc above a solid fusion.

After reoperation and physiotherapy the difference in the results was less marked. A satisfactory result was obtained in 76 per cent of the patients without fusion and in 80 per cent of the patients with the combined operation after an observation period of 6-7 years.

Comparison of the present series with results in a previous investigation of 292 patients with spinal fusion also speaks in favour of the combined operation, particularly in younger individuals.

ANTERIOR LUMBAR INTERBODY FUSION

K. Harry Sørensen
Odense, Denmark

Ninety-eight patients were treated with fusion (extraperitoneal technique, grafts from the iliac crest). Indications were incapacitating low back pain caused by degeneration of the 4th/5th lumbar disc or spondylolisthesis. 135 discs were degenerated, 114 were fused. There were no complications in 75 per cent, 11 had thrombophlebitis, two fatal pulmonary embolism, four slight infarctions and three severe atelectasis.

At follow up, 3-8 years later, the fusions were solid in 91 per cent and after reoperation in 94 per cent. Healing was not achieved in 21 per cent of the patients with spondylolisthesis. Seventy-three per cent felt better or cured. Thirty-one patients had constant pain (21 somatic explanation). Sixty per cent of the patients operated upon after the age of 45 received disablement pension.

The most suitable patients for the operation are those who are motivated, energetic, non-neurotic and not adipose.

LUMBAR INTERVERTEBRAL DISC HERNIATION IN CHILDREN AND ADOLESCENTS

H. Russwurm, F. Ronglan & I. Bjerkreim
Oslo, Norway

During the period 1965-1975 35 patients aged 10-18 years were operated upon for lumbar disc

herniation There were 19 girls and 16 boys The duration of symptoms was on average 20 months before diagnosis was made Only 10 patients were referred to the hospital under the diagnosis of ischialgia A previous trauma was found in nine cases

Subjective symptoms were mild Common objective findings were scoliosis kyphosis and back stiffness Changes in gait pattern were frequent Lasègue's test was positive at a few degrees Peripheral neurological signs were nearly always absent Our clinical material indicates there is a difference in symptomatology of lumbar disc herniation in children and adolescents as compared to adults

Mean follow up was 58 years Operative results were judged as excellent in 29 cases fair in 6 Scoliosis disappeared in all patients

FINDINGS AND RESULTS AFTER RE-OPERATION FOR LUMBAR DISC PROLAPSE

1. Vedsted
Oslo Norway

Fifty five out of 104 patients re-operated upon for lumbar disc prolapse replied to a questionnaire Perioperative findings at re-operation were prolapse in the same disc in 23 patients prolapse in another disc in 16 patients prolapse and perineural scarring in 10 patients and perineural scarring and/or bony excrescences in 31 patients Results were stated as excellent in 31 patients good by 29 patients and poor by 15 patients True recurrences had very good results but if in addition marked perineural scarring was found a little less than 50 per cent benefitted from the re-operation The same was true if at operation only perineural scarring and/or bony excrescences was found Myelography before re-operation gave positive or correct information in 63 per cent of cases Age and method of exposure did not seem to be of any significance The few backs with multiple operations had almost the same results as the others

LONG TERM LUMBAR INTERVENTRICAL DISC A 10-YEAR POSTOPERATIVE FOLLOW UP

Hennings M. Malsen Erik Th. Kjølbye & Finn Fuglestad
Nærbø, Denmark

A total of 174 patients were followed for variable periods. The results were as follows:

questionnaire	174
excellent	100
corporate	74

No fixation was performed

Mean age was 39.9 years and the female to male ratio was 1:2

At the 5 year follow up (96 patients), 56 per cent had regained full working capacity and had no symptoms or only mild ones 21 per cent had full working capacity but had some back symptoms and 27 per cent had a considerably lowered working capacity and/or major back complaints

The following factors correlated with a good prognosis: age less than 40 years no previous back complaints short duration of symptoms no operation preoperative work that was not back straining and high social position A positive correlation was found between high social position and no back strain at work Preoperative back strain at work had a minimal influence on the results whereas social position was the most important factor

Two to ten years postoperatively, the condition of the patients had changed only to a slight degree the number of patients deteriorating slightly exceeding the number of patients improving The postoperative symptoms of the individual patients were thus very stable after 2 years

RESULTS

Holstebro, Denmark

A follow up study was made on 544 patients operated on between 1962 and 1972 for herniated disc with removal of one or more discs 36 per cent were women 64 per cent were men The average age at the time of operation was 40.3 years The follow up period was from 4-14 years in average 8.4 years

The history was acute in 25 per cent of the cases Work was a direct causative factor in 40 per cent of the cases

About half of the patients sought non medical treatment (quack doctors or chiropractors) before hospitalization which consequently was delayed The results were better in the cases where the patients were operated upon within the first 2 months of the onset of symptoms and they were better in younger than in older patients There was a correlation between the myelography and the findings at operation in 91 per cent of the cases There were only a few complications of myelographies and operations and no mortality 20 per cent were operated upon without delay 75 per cent of the cases gained relief from pains in the back and the legs The number with paresthesias was significantly reduced but the number with disturbances of sensibility and reflexes was not reduced to the

next 24 hours regained normal function. The recovery rate then decreased steeply. Although all patients benefitted from surgery, incomplete recovery was the rule when there was a delay of more than one week.

UNILATERAL AND BILATERAL ARCOTOMY FOR LUMBAR DISC PROLAPSE WITH UNILATERAL SCIATICA: A FOLLOW UP STUDY OF 156 PATIENTS

Rolf Hagen & Lars H. Engesæter
Sandvika, Norway

The best surgical approach for lumbar disc lesions is still open to discussion and few comparative reports have been published.

Out of 250 patients operated upon for lumbar disc lesions between 1967-71, 156 were selected for review according to the following criteria: a) at least 3 months preoperative history; b) unilateral sciatica; c) L4/5 or L5/S1 disc lesion; d) no previous disc operation.

Bilateral arcotomy was performed on 67 patients (Group I) and unilateral arcotomy on 89 (Group II). The follow up was made 4-9 years postoperatively, and the patients in both groups were of similar age, sex and occupation. They had similar histories, symptoms and signs and myelographic findings. No patient in Group I needed reoperation for recurrent prolapse, whereas further surgery was required in four from Group II. At follow up 43 were symptom free and 24 improved in Group I, while 30 were symptom free, 44 improved, 2 unchanged and 12 worse in Group II. During the follow up period 13 per cent of patients in Group I and 26 per cent in Group II had severe attacks of sciatica. At the time of follow up 30 per cent in Group I and 51 per cent in Group II had low back pain.

Bilateral arcotomy proved to be the operation of choice. It caused no instability and did not predispose to the formation of adhesions opposite the lesion.

COMPARISON OF THE RESULTS IN PATIENTS OPERATED UPON FOR RUPTURED LUMBAR DISCS WITH AND WITHOUT SPINAL FUSION

Nils Eie
Oslo, Norway

From 1967-1969 simple extirpation of the ruptured disc and excoriation of the intervertebral space were performed in 131 patients, whereas a combined extirpation and lumbosacral fusion according to a modified Smith-Petersen's method was performed in 78 patients.

Follow up studies in 1974-1975 showed that during the first half postoperative year the results were similar in the two groups, with a satisfactory result in 89 per cent of the patients

without spinal fusion and in 88 per cent of the patients with fusion. Pain reappeared later in 26 per cent of the patients without fusion and in only 14 per cent of the patients with the combined operation. Nineteen patients or 10 per cent of the patients without spinal fusion were reoperated upon for recurrence or another ruptured disc. One was operated upon for extradural scar formation and adhesions, 11 had further courses in physiotherapy. Recurrence of a disc protrusion in the area of a solid fusion has not been observed. Two patients with fusion had reoperations for pseudarthrosis in the graft and one for a ruptured disc above a solid fusion.

After reoperation and physiotherapy the difference in the results was less marked. A satisfactory result was obtained in 76 per cent of the patients without fusion and in 85 per cent of the patients with the combined operation after an observation period of 6-7 years.

Comparison of the present series with results in a previous investigation of 282 patients with spinal fusion also speaks in favour of the combined operation, particularly in younger individuals.

ANTERIOR LUMBAR INTERBODY FUSION

A. Harry Sørensen
Odense, Denmark

Ninety-eight patients were treated with fusion (extraperitoneal technique) grafts from the iliac crest. Indications were incapacitating low back pain caused by degeneration of the 4th/5th lumbar disc or spondylolisthesis. 135 discs were degenerated, 114 were fused. There were no complications in 75 per cent, 11 had thrombophlebitis, two fatal pulmonary embolism, four slight infarctions and three severe atelectasis.

At follow up 3-8 years later the fusions were solid in 91 per cent and after reoperation in 94 per cent. Healing was not achieved in 21 per cent of the patients with spondylolisthesis. Seventy-three per cent felt better or cured. Thirty-one patients had constant pain (21 somatic explanation). Sixty per cent of the patients operated upon after the age of 45 received disablement pension.

The most suitable patients for the operation are those who are motivated, energetic, non-neurotic and not adipose.

LUMBAR INTERVERTEBRAL DISC HERNIATION IN CHILDREN AND ADOLESCENTS

H. Russwurm, I. Ronglan, C. I. Djerfheim
Oslo, Norway

During the period 1965-1975, 35 patients aged 10-18 years were operated upon for lumbar disc

herniation. There were 19 girls and 16 boys. The duration of symptoms was on average 20 months before diagnosis was made. Only 10 patients were referred to the hospital under the diagnosis of ischialgia. A previous trauma was found in nine cases.

Subjective symptoms were mild. Common objective findings were scoliosis, kyphosis and back stiffness. Changes in gait pattern were frequent. Lasègue's test was positive in a few degrees. Peripheral neurological signs were nearly always absent. Our clinical material indicates there is a difference in symptomatology of lumbar disc herniation in children and adolescents as compared to adults.

Mean follow-up was 5.8 years. Operative results were judged as excellent in 29 cases, fair in 7. Scoliosis disappeared in all patients.

FINDINGS AND RESULTS AFTER RE-OPERATION FOR LUMBAR DISC PROLAPSE

Oslo
Norway

Eighty-five out of 104 patients re-operated upon for lumbar disc prolapse replied to a questionnaire. Perioperative findings at re-operation were: prolapse in the same disc in 23 patients, prolapse in another disc in 16 patients, prolapse and perineural scarring in 10 patients and perineural scarring and/or bony excrescences in 31 patients. Results were stated as excellent in 31 patients, good by 29 patients and poor by 25 patients. True recurrences had very good results but in addition marked perineural scarring was found a little less than 50 per cent benefited from the re-operation. The same was true if at operation only perineural scarring and/or bony excrescences were found. Myelography before re-operation gave positive or correct information in 68 per cent of cases. Age and method of exposure did not seem to be of any significance. The few backs with multiple operations had almost the same results as the others.

IMPROVED LUMBAR INTERVERTEBRAL DISC AT 10 YEAR POSTOPERATIVE FOLLOW-UP

Hlemming F. Madsen, Erik Th. Kjølbye &
Finn Fuglsang
Copenhagen, Denmark

A total of 174 patients were followed for variable periods up to 10 years and evaluated by questionnaire. The operation was hemilaminectomy and evacuation of hernia and the intervertebral space. No fixation was performed.

Mean age was 39.9 years and the female to male ratio was 1.2.

At the 5-year follow-up (96 patients) 56 per cent had regained full working capacity and had no symptoms or only mild ones. 21 per cent had full working capacity but had some back symptoms and 27 per cent had a considerably lowered working capacity and/or major back complaints.

The following factors correlated with a good prognosis: age less than 40 years, no previous back complaints, short duration of symptoms at operation, preoperative work that was not back straining, and high social position. A positive correlation was found between high social position and no back strain at work. Preoperative back strain at work had a minimal influence on the results, whereas social position was the most important factor.

Two to ten years postoperatively the condition of the patients had changed only to a slight degree: the number of patients deteriorating slightly exceeded the number of patients improving. The postoperative symptoms of the individual patients were thus very stable after 2 years.

FINAL RESULT STUDY OF 544 PATIENTS OPERATED UPON FOR HERNIATED INTERVERTEBRAL LUMBAR DISC

V. Damholt & P. Otlsen
Holstebro, Denmark

A follow-up study was made on 544 patients operated on between 1962 and 1972 for herniated disc with removal of one or more discs. 36 per cent were women, 64 per cent were men. The average age at the time of operation was 40.3 years. The follow-up period was from 4 to 14 years, in average 8.4 years.

The history was acute in 75 per cent of the cases. Work was a direct causative factor in 40 per cent of the cases.

About half of the patients sought non-medical treatment (quack-doctors or chiropractors) before hospitalization, which consequently was delayed. The results were better in the cases where the patients were operated upon within the first 2 months of the onset of symptoms and they were better in younger than in older patients. There was a correlation between the myelography and the findings at operation in 91 per cent of the cases. There were only a few complications of myelographies and operations and no mortality. 92 per cent were operated upon without delay. 75 per cent of the cases gained relief from pains in the back and the legs. The number with paresthesia was significantly reduced but the number with disturbances of sensibility and reflexes was not reduced to the

next 24 hours regained normal function. The recovery rate then decreased steeply. Although all patients benefitted from surgery, incomplete recovery was the rule when there was a delay of more than one week.

UNILATERAL AND BILATERAL ARCOTOMY FOR LUMBAR DISC PROLAPSE WITH UNILATERAL SCIATICA: A FOLLOW UP STUDY OF 156 PATIENTS

Rolf Hagen & Lars B. Engesaeter
Sandvika, Norway

The best surgical approach for lumbar disc lesions is still open to discussion and few comparative reports have been published.

Out of 250 patients operated upon for lumbar disc lesions between 1967-71, 156 were selected for review according to the following criteria: a) at least 6 months preoperative history, b) unilateral sciatica, c) L4/5 or L5/S1 disc lesion, d) no previous disc operation.

Bilateral arcotomy was performed on 67 patients (Group I) and unilateral arcotomy on 89 (Group II). The follow up was made 4-9 years postoperatively and the patients in both groups were of similar age, sex and occupation. They had similar histories, symptoms and signs and myelographic findings. No patient in Group I needed reoperation for recurrent prolapse, whereas further surgery was required in four from Group II. At follow up, 43 were symptom free and 24 improved in Group I, while 30 were symptom free, 44 improved, 2 unchanged and 12 worse in Group II. During the follow up period, 13 per cent of patients in Group I and 26 per cent in Group II had severe attacks of sciatica. At the time of follow up, 30 per cent in Group I and 51 per cent in Group II had low back pain.

Bilateral arcotomy proved to be the operation of choice. It caused no instability and did not predispose to the formation of adhesions opposite the lesion.

COMPARISON OF THE RESULTS IN PATIENTS OPERATED UPON FOR RUPTURED LUMBAR DISCS WITH AND WITHOUT SPINAL FUSION

Nils Eie
Oslo, Norway

From 1967-1969, simple extirpation of the ruptured disc and excision of the intervertebral space were performed in 191 patients, whereas a combined extirpation and lumbosacral fusion according to a modified Smith-Petersen method was performed in 68 patients.

Follow up studies in 1974-1975 showed that during the first half postoperative year the results were similar in the two groups, with a satisfactory result in 80 per cent of the patients

without spinal fusion and in 88 per cent of the patients with fusion. Pain reappeared later in 26 per cent of the patients without fusion and in only 14 per cent of the patients with the combined operation. Nineteen patients or 10 per cent of the patients without spinal fusion were reoperated upon for recurrence or another ruptured disc. One was operated upon for extradural scar formation and adhesions. 11 had further courses in physiotherapy. Recurrence of a disc protrusion in the area of a solid fusion has not been observed. Two patients with fusion had reoperations for pseudarthrosis in the graft, and one for a ruptured disc above a solid fusion.

After reoperation and physiotherapy, the difference in the results was less marked. A satisfactory result was obtained in 76 per cent of the patients without fusion and in 85 per cent of the patients with the combined operation after an observation period of 6-7 years.

Comparison of the present series with results in a previous investigation of 282 patients with spinal fusion also speaks in favour of the combined operation, particularly in younger individuals.

ANTERIOR LUMBAR INTERBODY FUSION

K. Harry Sørensen
Odense, Denmark

Ninety-eight patients were treated with fusion (extraperitoneal technique, grafts from the iliac crest). Indications were incapacitating low back pain caused by degeneration of the 4th/5th lumbar disc or spondylolisthesis. 135 discs were degenerated, 114 were fused. There were no complications in 75 per cent. 11 had thrombophlebitis, two fatal pulmonary embolism, four slight infarctions and three severe atelectasis.

At follow up 3-8 years later, the fusions were solid in 91 per cent and after reoperation in 94 per cent. Healing was not achieved in 9 per cent of the patients with spondylolisthesis. Seventy-three per cent felt better or cured. Thirty-one patients had constant pain (21 somatic explanation). Sixty per cent of the patients operated upon after the age of 45 received disablement pension.

The most suitable patients for the operation are those who are motivated, energetic, non-neurotic and not adipose.

LUMBAR INTERTRANSVERSE DISC FUSION IN CHILDREN AND ADOLESCENTS

H. Russworm, I. Ronglan & I. Bjerkreim
Oslo, Norway

During the period 1965-1975, 35 patients aged 10-18 years were operated upon for lumbar disc

herniation There were 10 girls and 16 boys The duration of symptoms was on average 20 months before diagnosis was made Only 10 patients were referred to the hospital under the diagnosis of ischialgia A previous trauma was found in nine cases

Subjective symptoms were mild Common objective findings were scoliosis kyphosis and back stiffness Changes in gait pattern were frequent Latigue's test was positive at a few degrees Peripheral neurological signs were nearly always absent Our clinical material indicates there is a difference in symptomatology of lumbar disc herniation in children and adolescents as compared to adults

Mean follow up was 5.8 years Operative results were judged as excellent in 29 cases fair in 7 Scoliosis disappeared in all patients

FINDINGS AND RESULTS AFTER RE-OPERATION FOR LUMBAR DISC HERNIATION 4 Hospitals Oslo Norway

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LONG TERM FOLLOW UP OF LUMBAR INTERVERTEBRAL DISC A 10 YEAR POSTOPERATIVE FOLLOW UP Firmen F. Nilsen Frih Th. Kjølbye & F. N. Fuglsang Sønderborg Denmark

A total of 174 patients were followed for variable periods up to 10 years and evaluated by questionnaire The operation was hemilaminectomy and evacuation of hernia and the intervertebral space No fixation was performed

Mean age was 39.9 years and the female to male ratio was 1:1

At the 5 year follow up (96 patients) 56 per cent had regained full working capacity and had no symptoms or only mild ones 21 per cent had full working capacity but had some back symptoms and 27 per cent had a considerably lowered working capacity and/or major back complaints

The following factors correlated with a good prognosis: age less than 40 years no previous back complaints short duration of symptoms at operation preoperative work that was not back straining and high social position A positive correlation was found between high social position and no back strain at work Preoperative back strain at work had a minimal influence on the results whereas social position was the most important factor

Two to ten years postoperatively the condition of the patients had changed only to a slight degree the number of patients deteriorating slightly exceeding the number of patients improving The postoperative symptoms of the individual patients were thus very stable after 2 years

FINAL RESULT STUDY OF 544 PATIENTS OPERATED ON BETWEEN 1962 AND 1972

1. CLINICAL SUMMARY

A follow up study was made on 544 patients operated on between 1962 and 1972 for herniated disc with removal of one or more discs 35 per cent were women 64 per cent were men The average age at the time of operation was 40.3 years The follow up period was from 4 to 14 years in average 8.4 years

The history was acute in 25 per cent of the cases Work was a direct causative factor in 40 per cent of the cases

About half of the patients sought non medical treatment (quack-doctors or chiropractors) before hospitalization which consequently was delayed The results were better in the cases where the patients were operated upon within the first 2 months of the onset of symptoms and they were better in younger than in older patients There was a correlation between the myelography and the findings at operation in 91 per cent of the cases There were only a few complications of myelographies and operations and no mortality 25 per cent were operated upon without delay 75 per cent of the cases gained relief from pains in the back and the legs The number with paresis was significantly reduced but the number with disturbances of sensibility and reflexes was not reduced to the

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The best surgical approach for lumbar disc lesions is still open to discussion, and few comparative reports have been published.

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Bilateral arcotomy was performed on 67 patients (Group I) and unilateral arcotomy on 89 (Group II). The follow-up was made 4-9 years postoperatively, and the patients in both groups were of similar age, sex and occupation. They had similar histories, symptoms and signs and myelographic findings. No patient in Group I needed reoperation for recurrent prolapse whereas further surgery was required in four from Group II. At follow up 43 were symptom free and 24 improved in Group I, while 30 were symptom free, 44 improved, 2 unchanged and 12 worse in Group II. During the follow up period 13 per cent of patients in Group I and 26 per cent in Group II had severe attacks of sciatica. At the time of follow up 30 per cent in Group I and 51 per cent in Group II had low back pain.

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LUMBAR INTERVERTEBRAL DISC FUSION IN CHILDREN AND ADOLESCENTS

H. Russwurm, E. Ronglan & I. Bjørleim
Oslo, Norway

During the period 1965-1975 35 patients aged 10-18 years were operated upon for lumbar disc

months because of lack of improvement. The remaining six do not differ significantly from the operated cases.

THE TREATMENT OF POSTOPERATIVE DISCITIS WITH ANTICOAGULATION

B Raagard P Helin A Jarlov & P Ahlgren
Copenhagen Denmark

An account is given of 15 patients with postoperative discitis who were treated with anti-coagulants Indometacin and bed rest. This treatment had the result that patients confined to bed were relieved of their symptoms after about 10 days treatment and later could be mobilized. With the aid of a lumbo sacral support they could continue treatment as outpatients. The effect of anticoagulants suggested that a local red hypercoagulability might play a certain role either as a pathogenetic or a pathophysiological factor. In the present series the clinical manifestations were: 1) constant piercing local pain in the back 2) tenderness to percussion at the sites of the affected vertebrae 3) diffuse pain localized to both lower extremities and tenderness to palpation at the sides of the long saphenous vein and the femoral triangle (Scarpas triangle) 4) acute abdominal pain occasionally combined with paresis of the urinary bladder. The clinical symptoms occurred about weeks before the vertebral lesions were roentgenologically demonstrable. Laboratory tests early in the course of the disease failed to provide data by which the diagnosis could be verified.

RESECTION OF PROCESSUS SPINOSUS IN 102 PATIENTS WITH CHRONIC LOW BACK PAIN

H Iuni & P Ramaling
Arlhus Denmark

Degenerative changes in the lumbar inter-spinal ligaments and processus spinosus may be a cause of low back pain. During the period 1973-1975 in 106 patients suffering from chronic low back pain a localized tenderness was demonstrated between two lumbar processus spinosus. X-ray showed kissing spine and degeneration of one or more lumbar discs. The low back pain disappeared for 2-4 hours following repeated injection of 3 ml local anaesthetic into the interspinal ligaments and the operation was performed with resection of the lumbar processus spinosus and the interspinal ligaments. The duration of the operation was 15-30 minutes and the patients were discharged on the fifth postoperative day.

The average age of the patients was 47 years and the duration of symptoms averaged 9½

years. In a follow up of 102 patients 39 females and 63 males 9 months to 10 years after the operation 42 patients were improved with disappearance or relief of symptoms. Forty-two patients were unchanged and in 18 patients the pain was aggravated. Several patients in the last two groups however had relief of symptoms a few months after the operation.

MUSCULAR ATROPHY IN THE PROLAPSED LUMBAR INTERVERTEBRAL DISC

K Haug
Oslo, Norway

In 30 per cent of sciatica patients differences in circumference usually 1 cm can be measured in the lower extremities. In a leg segment 10 cm high considered as a cone right truncated 1 cm difference in circumference will represent a volume reduction of 60-90 ml. The principle of volume measurement is to transfer a leg segment to a cylinder of the same height. Then the segment volume equals the cylinder volume minus the rest volume.

Comparable segments are defined by two parallel planes vertical to the leg axis at a fixed reciprocal distance and at the same height over the base of the foot. For measurements one rack for the thigh and one for the calf and adequate cylinders are needed. The leg encircled by the cylinder is placed in the rack with a levelled plate of foam rubber under the cylinder. Thin plastic foil covers the cavity which is filled up with liquid. This liquid is then transferred to the other leg under same measuring conditions. The reduction of volume in one segment equals the difference between the two rest volumes. Volume differences are due to muscular atrophy which may have local causes as well as being a result of affections of the lower motor neurones of various aetiologies. It indicates destruction of these cells. When a reduction of volume is measured during a disc protrusion syndrome the symptom will be of great significance.

FACTORS INFLUENCING WORKING CAPACITY FOLLOWING DISC SURGERY

Y Surén
Borås, Sweden

Results of lumbar disc surgery in terms of total postoperative disability time and return to work were recorded. The analysis was based on a total of 366 patients. The number of recurrences and the percentage of disablement pensions were directly related to the length of the observation time.

A short interval between the onset of leg pain and the time of the operation was an important

same degree. The factor which most inhibited work was pain in the back and legs whereas paresis hardly ever caused inability to work.

1000 MYELOGRAPHIES WITH MEGLUMINE IOTHALAMAT (CONRAY MEGU VIN 282)

Lars Ande

Sandnes Norway

One thousand myelographies were performed between 1969 and 1974. A total of 934 patients were examined (627 men and 307 women), 111 patients twice or more. Most of the patients (306) were 40-49 years, nine were 10-19 and five were 70-79 years old.

The myelographies showed prolapses in 404 cases. Among those 376 were operated on and in 345 cases true prolapses were found whereas protrusion or degeneration of the disc was found in 27 cases. Roentgenologically there was a good correlation in 337 cases, fairly good in 26 cases and not so good in 13 cases.

In 19 of the myelographies regions of poor contrast or total blockage were found. Sixteen of these were operated on and prolapses were found in 11 cases. One patient had a malignant tumour and two had lumbar stenosis. Roentgenologically there was good correlation in 14 cases, it was fairly good in one case and not so good in one case.

In 315 cases only minor changes such as shortening of the root sleeves were found. A total of 153 patients were operated on, 55 with prolapses and 97 with protrusion or degeneration of the disc. Roentgenological examination showed a good correlation in 97 cases, fairly good in 97 cases and not so good in 10 cases.

In 262 myelographies there were negative results. Twenty six of them were operated on and in six cases prolapses were found. Protrusions were found in two cases and negative results in 18 cases. Roentgenologically there was a good correlation in 18 cases, fairly good in two cases and not so good in six cases.

Cramp was registered in four cases. In four other cases jerks of the lower extremities were experienced. Fifteen suffered from headache and partial collapse was registered in five cases. Cramp and jerks were immediately relieved by intravenous injection of Diazepam (Vallum) possibly repeated a few times.

EFFECTS OF CHYMOPAPAIN ON NERVE TISSUE

B Rydevik, P I Brdnemarl, C Nordborg, W G McLean, J Sjöstrand & M Fogelberg
Goteborg Sweden

Chymopapain chemonucleolysis as treatment for intervertebral disc disease has been widely used during the last few years. The literature

on the subject reports differing opinions concerning indications, results, complications and the possible mechanism by which chymopapain relieves low back pain and sciatica.

Chymopapain which is injected into an intervertebral disc may leak out to the surrounding tissues and reach neural elements e.g. local sensory nerves and a nerve root. The effects of chymopapain on such peripheral nerve tissue have been investigated in the present study. The tibial nerves of 11 rabbits were used for the experimental model and the effects of 1 ml of 0.4 per cent chymopapain were compared with those of 1 ml of isotonic saline. The following parameters were investigated:

1. Intraneural microcirculation and permeability of the perineurial sheath (fluorescent microscopy)
2. Axonal transport of proteins (radioactive protein determination)
3. Nerve function (neurophysiology)
4. Nerve fibre and intraneural connective tissue reactions (neurohistology)

The results showed that chymopapain had no acute effects on impulse conductivity or axonal transport. The enzyme induced however intraneural oedema formation by increasing the permeability of the intraneural microvessels and the perineurial sheath. The long term effects were nerve fibre degeneration and intraneural fibrosis formation leading to impaired nerve function.

CHYMOPAPAIN INJECTION FOR DISC HERNIA —PRELIMINARY RESULTS OF A CONTROLLED STUDY

A Vachemson, A Ejeshär, P Herberts & E Lysell
Goteborg Sweden

Although chymopapain injection treatment for disc hernias has recently been stopped in the USA it is still in use in Europe and Canada. In order to compare the results of chymopapain injection versus conventional disc surgery a controlled study on patients with typical L5 syndrome and a positive water soluble contrast myelography was performed.

Preliminary results of this strictly controlled study (half of the patients were operated upon and the other half received chymopapain intradiscally) show that injection treatment in this series of 18 patients (9 + 9) followed up for at least half a year by an independent examiner appears to give some immediate advantages in the form of a shorter stay in hospital and a shorter sick leave period but it does not give as good end results as surgery. Thus three out of nine cases were reoperated upon within 2

months because of lack of improvement. The remaining six do not differ significantly from the operated cases.

TREATMENT OF POSTOPERATIVE DISCITIS WITH ANTICOAGULATION

H Raagard, P Helin, A Jarlov & P Ahlgren
Copenhagen, Denmark

An account is given of 15 patients with postoperative discitis who were treated with anti-coagulants Indometacin and bed rest. This treatment had the result that patients confined to bed were relieved of their symptoms after about 10 days treatment and later could be mobilized. With the aid of a lumbo-sacral support they could continue treatment as outpatients. The effect of anticoagulants suggested that a localised hypercoagulability might play a certain role either as a pathogenetic or a pathophysiological factor. In the present series the clinical manifestations were: 1) constant piercing local pain in the back, 2) tenderness to percussion at the sites of the affected vertebrae, 3) diffuse pain localized to both lower extremities and tenderness to palpation at the sides of the long saphenous vein and the femoral triangle (Scarspa's triangle), 4) acute abdominal pain occasionally combined with paresis of the urinary bladder. The clinical symptoms occurred about 2 weeks before the vertebral lesions were roentgenologically demonstrable. Laboratory tests early in the course of the disease failed to provide data by which the diagnosis could be verified.

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B Lund & M Rasmussen
Århus, Denmark

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The average age of the patients was 46 years and the duration of symptoms averaged 9½

years. In a follow up of 102 patients 39 females and 63 males 9 months to 10 years after the operation 42 patients were improved with disappearance or relief of symptoms. Forty-two patients were unchanged and in 18 patients the pain was aggravated. Several patients in the last two groups however had relief of symptoms a few months after the operation.

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K Haug
Gjøvik, Norway

In 30 per cent of sciatica patients differences in circumference usually 1 cm can be measured in the lower extremities. In a leg segment 10 cm high, considered as a cone right truncated, 1 cm difference in circumference will represent a volume reduction of 60-90 ml. The principle of volume measurement is to "transfer" a leg segment to a cylinder of the same height. Then the segment volume equals the cylinder volume minus the rest volume.

Comparable segments are defined by two parallel planes vertical to the leg axis at a fixed reciprocal distance and at the same height over the base of the foot. For measurements, one rack for the thigh and one for the calf and adequate cylinders are needed. The leg encircled by the cylinder is placed in the rack with a levelled plate of foam rubber under the cylinder. Thin plastic foil covers the cavity which is filled up with liquid. This liquid is then transferred to the other leg under same measuring conditions. The reduction of volume in one segment equals the difference between the two rest volumes. Volume differences are due to muscular atrophy which may have local causes as well as being a result of affections of the lower motor neurones of various aetiologies. It indicates destruction of these cells. When a reduction of volume is measured during a disc protrusion syndrome the symptom will be of great significance.

FACTORS INFLUENCING WORKING CAPACITY FOLLOWING DISC SURGERY

I Sjöström
Borås, Sweden

Results of lumbar disc surgery in terms of total postoperative disability time and return to work were recorded. The analysis was based on a total of 366 patients. The number of recurrences and the percentage of disablement pensions were directly related to the length of the observation time.

A short interval between the onset of leg pain and the time of the operation was an important

same degree. The factor which most inhibited work was pain in the back and legs, whereas paresis hardly ever caused inability to work.

1000 MYELOGRAPHIES WITH MEGLUMINE IOTHALAMAT (CONRAY MYGLUMIN 282)

Lars Anda

Sandnes, Norway

One thousand myelographies were performed between 1969 and 1974. A total of 934 patients were examined (627 men and 307 women), 66 patients twice or more. Most of the patients (306) were 40-49 years, nine were 10-19 and five were 70-79 years old.

The myelographies showed prolapses in 404 cases. Among those 376 were operated on and in 345 cases true prolapses were found, whereas protrusion or degeneration of the disc was found in 27 cases. Roentgenologically there was a good correlation in 337 cases, fairly good in 26 cases and not so good in 13 cases.

In 19 of the myelographies regions of poor contrast or total blockage were found. Sixteen of these were operated on, and prolapses were found in 11 cases. One patient had a malignant tumour and two had lumbar stenosis. Roentgenologically there was good correlation in 14 cases, it was fairly good in one case and not so good in one case.

In 316 cases only minor changes, such as shortening of the root sleeves, were found. A total of 153 patients were operated on, 55 with prolapses and 97 with protrusion or degeneration of the disc. Roentgenological examination showed a good correlation in 97 cases, fairly good in 97 cases and not so good in 10 cases.

In 262 myelographies there were negative results. Twenty-six of them were operated on, and in six cases prolapses were found. Protrusions were found in two cases and negative results in 18 cases. Roentgenologically there was a good correlation in 18 cases, fairly good in two cases and not so good in six cases.

Cramp was registered in four cases. In four other cases jerks of the lower extremities were experienced. Fifteen suffered from headache, and partial collapse was registered in five cases. Cramp and jerks were immediately relieved by intravenous injection of Diazepam (Valium) possibly repeated a few times.

EFFECTS OF CHYMOPAPAIN ON NERVE TISSUE

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Chymopapain chemonucleolysis as treatment for intervertebral disc disease has been widely used during the last few years. The literature

on the subject reports differing opinions concerning indications, results, complications and the possible mechanism by which chymopapain relieves low back pain and sciatica.

Chymopapain which is injected into an intervertebral disc may leak out to the surrounding tissues and reach neural elements, e.g. local sensory nerves and a nerve root. The effects of chymopapain on such peripheral nerve tissue have been investigated in the present study. The tibial nerves of 63 rabbits were used for the experimental model and the effects of 1 ml of 0.4 per cent chymopapain were compared with those of 1 ml of isotonic saline. The following parameters were investigated:

- 1 Intraneural microcirculation and permeability of the perineurial sheath (fluorescent microscopy)
- 2 Axonal transport of proteins (radioactive protein determination)
- 3 Nerve function (neurophysiology)
- 4 Nerve fibre and intraneural connective tissue reactions (neurohistology)

The results showed that chymopapain had no acute effects on impulse conductivity or axonal transport. The enzyme induced, however, intraneural oedema formation by increasing the permeability of the intraneural microvessels and the perineurial sheath. The long term effects were nerve fibre degeneration and intraneural fibrosis formation, leading to impaired nerve function.

CHYMOPAPAIN INJECTION FOR DISC HERNIA — PRELIMINARY RESULTS OF A CONTROLLED STUDY

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Although chymopapain injection treatment for disc hernias has recently been stopped in the USA it is still in use in Europe and Canada. In order to compare the results of chymopapain injection versus conventional disc surgery a controlled study on patients with typical L5 syndrome and a positive water soluble contrast myelography was performed.

Preliminary results of this strictly controlled study (half of the patients were operated upon and the other half received chymopapain intradiscally) show that injection treatment in this series of 18 patients (9 + 9) followed up for at least half a year by an independent examiner, appears to give some immediate advantages in the form of a shorter stay in hospital and a shorter sick leave period but it does not give as good end results as surgery. Thus three out of nine cases were reoperated upon within 2

achieved in 55 patients (60.4 per cent) satisfactory in 23 (24.1 per cent) and unsatisfactory in 13 (15.5 per cent). Posterolateral fusion seems to be preferable to posterior fusion.

A ROENTGEN STEREOPHOTOGRAMMETRIC METHOD FOR STUDYING THE HEALING OF FUSIONS OF THE SPINE

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A roentgen stereophotogrammetric method is described for studying the movements between separate segments of the vertebrae following fusion operations. This method determines the rotations and translations about the X, Y and Z axes with great accuracy. Rotations down to 0.1° and translations down to 0.1 mm are estimated. Three indicators are inserted in each vertebra. Two exposures of the patient are obtained simultaneously from two roentgen tubes on one film. A calibration cage is also double exposed on the same film. In the walls of the cage indicators with known three-dimensional positions are inserted. The measured two-dimensional positions on the film of the indicators in the cage and the object are then treated by data processing as described by Selvik (1974). The coordinates of the indicators of the spine are then estimated in a Cartesian co-ordinate system bound to the calibration cage and the general displacement of each vertebra in relation to another is described.

With this method the decreased movements in a fusion mass (the healing of a fusion operation) can be followed and defective healing (pseudarthrosis) will thus be detected. After a successful operation the three-dimensional loss of correction can also be described.

Two cases with a fusion operation—one with a spondylolisthesis L5-S1 and the other with an idiopathic scoliosis—were demonstrated.

CAN SKELETAL MUSCLE FIBRE ATROPHY IN A CAST BE PREVENTED BY EXERCISE?

Bengt Saltin
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Skeletal muscle fibres can be divided into two main types designated Type I (red or slow) and Type II (white or fast) fibres. The latter group can be further divided into A and B types where the II B fibres are the typical white fibres with a very low oxidative potential and poor endurance. Human skeletal muscles are a mixture of fibres with an average distribution of 50 per cent Type I, 34 per cent Type II A and 16 per cent Type II B. The relative distribution of fibres varies markedly between individuals but is much more consistent in muscles from the

same person. No definite proof exists to show that a conversion of Type I to Type II fibres may occur with inactivity or activity but the size of the fibres as well as their metabolic potential varies in relation to the use or disuse of the fibres.

Five to six weeks in a cast results in a significant reduction in size of both fibre types and in oxidative and glycolytic enzyme activity. These changes may explain the reduced strength and endurance of the muscles found after an extremity has been in a cast. The performance of maximal isometric contractions of the muscles while in a cast reduces the hypotrophy of Type II fibres which appear to be the fibre which is recruited predominantly in this type of contraction. In order to activate the Type I fibres and train their oxidative potential, light contractions performed over a period of 15–30 minutes are needed. Combining these two forms of exercises the size of the fibres and their metabolic capacity will still be reduced after having the extremity in a cast but only to a very minor degree. The advantage is that the recovery period can be shortened and normal activities and athletic training can be resumed earlier.

LIGAMENT INJURIES OF THE KNEE JOINT—THE DIAGNOSIS AND TREATMENT

Jan Gillquist, Sten Otto Liljedahl
Gunnar Hagberg & Åke Öretorp
Linköping, Sweden

The difficulties encountered in the diagnosis of knee injuries are well known. Liljedahl et al have shown that the uncertainty of clinical examination can be reduced by examination under anaesthesia or arthrography. Combined injuries present more difficulties than single

injuries. A small arthroscope introduced into the joint through the patellar tendon (Gillquist & Hagberg 1976). The joint is flushed with sterile water by an infusion pump. The water leaves the joint through a specially made arthroscopy cannula (Stille, Werner, Stockholm, Sweden). For the inspection of the posteromedial and the posterolateral compartments a 70° telescope is used whereas the rest of the joint is examined through the normal 30° telescope. We have examined 300 injured knees by this method. Of special interest is a study of 84 examinations in the acute stage (Gillquist, Hagberg, Öretorp to be published). Haemarthrosis was usually due to rupture of the anterior cruciate ligament in combination with other injuries. Locking of the knee joint was an unreliable sign of a torn

prognostic factor. Patients with negative neurological and myelographic findings were poor candidates for disc surgery.

Fifty-seven per cent of the patients continued the same work, 24 per cent of the patients changed their work, 24 per cent received disablement pensions.

PSYCHIC AND SOCIAL FACTORS IN THE TREATMENT OF PATIENTS WITH LUMBAR DISC PROLAPSE

A. Halttunen & I. E. Laurent
Helsinki, Finland

This series consists of 54 patients suffering from low back pain and sciatica. Of these, 39 were operated on, ten received physiotherapy, and five manipulation of the back under anaesthesia. The patients were examined by a clinical psychologist before treatment and 6 and 12 months after treatment in order to create a model to predict the results of treatment. Medical factors (result of treatment), social factors (ability to work), and psychic factors (the patient's mental health and his opinion of the result of treatment) were taken into account. The results of treatment could be predicted by taking six factors into account in 55 per cent of the cases, and the ability to return to work, also using six factors, could be predicted in 68 per cent of the cases.

The following medical factors indicated a good result: no previous operations on the back, typical signs of a protruded disc, a short period of pain and of sick leave before treatment, and operative treatment.

The most important social factors were as follows: intellectual work or labour where the working position could be changed, sick leave of less than 3 months, education more than that of elementary school, operation as a semi-private patient, and age under 30 or over 40.

The most important psychic factors were the patient considered it absolutely necessary to return to work, keen intelligence, no visits to the doctor for trivialities, hardly any psychic or psychosomatic signs, and the patient was self-reliant, his behaviour open, and his motivation to work good even overemphasized.

The most important factors in the rehabilitation of patients with low back pain and sciatica are the duration of the disease and the influence of the disease on the ability to work and on the existing possibilities for the patient.

In a chronic disease the process of rehabilitation is a psycho-socio-economic problem rather than a medical one. An examination by a clinical psychologist may help the orthopaedic surgeon to avoid unnecessary operations on the back.

THE SOCIAL STATE OF 615 PATIENTS BEFORE AND AFTER OPERATION FOR HERNIATED LUMBAR DISC

P. Ollsen & V. Damholt
Holstebro, Denmark

A total of 615 patients were operated upon for herniated lumbar disc. 544 of these patients (92 per cent of the patients alive) were seen during a follow-up investigation which included a clinical examination and an interview concerning the social and economic consequences of their disease. The mean period of observation was 9 years.

A majority of the patients operated upon for lumbar disc prolapse had a low level of education and did hard physical work. Eighty per cent of the patients resumed work after the operation. 286 patients had changed their job at the follow-up investigation, 549 per cent of these because of the disease. Ninety-three patients were referred to centres for rehabilitation. 473 per cent with success. Two thirds of the patients who did not succeed in rehabilitation were over the age of 45 years.

OPERATIVE TREATMENT OF SPONDYLOLISTHESIS IN YOUNG PATIENTS

I. F. Laurent & A. Osterman
Helsinki, Finland

A series of 91 patients under 20 years of age with lytic lumbar spondylolisthesis, treated operatively at the Orthopaedic Hospital of the Invalid Foundation, Helsinki, are presented. Sixty-six patients (73 per cent) showed a displacement of more than 30 per cent on admission. If the displacement exceeds 30 per cent it often progresses to a total or subtotalolisthesis, fusion should be performed before the slipping exceeds one third of the length of the vertebral body. Posterior fusion was performed in 78 patients (87 per cent). In connection with fusion, laminectomy was performed in 13 patients. Ventral fusion was performed in three patients and posterolateral fusion in 10 cases of these four as a second operation. Laminectomy only was carried out in four patients, three of them having a total listhesis and one a massive disc herniation. Laminectomy without fusion should be performed only in exceptional cases in young patients.

Non union or uncertain union after the first operation occurred in 17 patients (19.5 per cent). Of these, 13 patients were reoperated upon. Two patients had two reoperations. The degree of slipping at the operation did not influence the results. A progression of displacement was observed in 14 patients in spite of dorsal fusion. The final results show that good results were

patients had resumed their sporting activities completely whereas eight had decreased their activity as far as track training was concerned. Two patients had given up their sport although they gave reasons other than lower limb pain for this decision.

RUPTURE OF THE TENDO ACHILLIS A FOLLOW UP INCLUDING MEASUREMENT OF THE POWER OF PLANTAR FLEXION

A. H. Termansen & I. Damholt
Odense Denmark

During the period 1970-1974 71 patients were treated for subcutaneous ruptures of the tendo Achillis at the Orthopaedic Department Odense University Hospital, Denmark. Sport was the reason for 81.8 per cent of the lesions. Operative treatment comprised suture and plastic repair with a strip of the tendon of the gastrocnemius muscle in 38 patients, suture only in 16 patients and non operative treatment with plaster of Paris in 12 patients. At follow up from 14-77 months after the injury 66 patients or 97.1 per cent of all surviving patients were re-examined. Complications were most common in patients treated surgically with plastic repair. Significant complaints were found in 12.1 per cent of the patients while 89.1 per cent had no symptoms at all. The circumference of the calf was less in the affected than in the unaffected limbs ($P < 0.001$). The power of plantar flexion averaged 10.1 per cent less in the affected than in the unaffected limbs ($P < 0.001$) but only slight positive correlation was found between circumference and power ($r = 0.32$). In two patients only the working capacity was reduced because of the injury but seven out of 54 patients had abandoned sport because of the injury and 10 for some other reason. The power of plantar flexion correlated in most cases with the ability to return to sport.

PROGNOSTICATED AND ACTUAL DURATION OF INCAPACITY AFTER SPORTS INJURIES

H. Victor Nielsen & E. Krøgh Petersen
Odense Denmark

A total of 721 emergency room outpatients with regular work aged 15-65 years were followed up and the period of incapacity after their accident was studied. Eighty patients were hurt while playing sport. The casualty officer estimated the expected number of lost days (prognosticated incapacity). By letter the patients gave information as to what date they started work again (actual incapacity). Eighty nine per cent replied.

A graphic picture of the prognosticated and the actual incapacity period showed two almost

parallel curves indicating a constant and therefore acceptable prognostication. In the total material there was an underestimation of the time of incapacity. The ratio between prognosticated and actual incapacity following sports injuries was 1.27. Sports injuries resulted in a longer period of incapacity than other injury groups with identical diagnoses (e.g., industrial accidents). The mean prognosticated incapacity period for sports injuries amounted to 10.2 days—the actual was 12.9 days. The difference between the two figures was reduced in cases of overestimation of the incapacity. The average error of judgment for sports injuries was 7 days and it was a little less for light traffic and industrial accidents.

Prognosticated time of incapacity in number of days was a simple means of measuring the severity of the lesions, and in our material it was a considerably better measuring device than the H diagnosis and the E code.

RADIOGRAPHIC MEASUREMENT OF THE STABILITY OF THE KNEE JOINT IN INJURIES TO THE LIGAMENTS BASED ON A MATERIAL OF ATHLETES

Klaus Jacobsen
Gentofte Denmark

The measuring method consisted of mechanical action upon the joint in different directions by well defined hydraulic forces, using a special apparatus: the gonylaxometer while radiographs were exposed. Looseness was measured on the film. Normal values were arrived at by studying a material of 50 subjects. The 97.5 per cent upper limits for normal knees were 2 mm for medial and lateral collateral looseness and 3 mm for anterior as well as posterior looseness (measured as the difference between the sound and the traumatized knee). The pathological material comprised 153 knee lesions, the majority in athletes. The stress radiographic findings were compared with the operative findings and with the primary clinical evaluation and the

... as a diagnostic method in acute casualties was carried out by calculation of the predictive values of positive and of negative tests. Local anaesthesia was used but not caused by complex demonstrated

meniscus the diagnosis being correct in only half the cases. In a small series we have also removed free bodies percutaneously under direct inspection through the arthroscope.

MINOR SPORTS INJURIES A 7 YEAR MATERIAL

S Nilsson & A Roaas
Oslo and Sandvika Norway

At a clinic for sports injuries in Oslo 2729 athletic injuries have been treated over the past 7 years. The injuries were mostly minor, interfering with the athletes' ability to train or compete. Almost 50 per cent occurred in soccer which reflects that soccer is the most popular sport in Norway. More surprisingly injuries in runners came second. Eighty per cent of these injuries were over use or stress injuries. In contact sports 80 per cent were acute traumatic injuries. Whereas the acute injuries differed little from similar injuries suffered in non athletes 74 per cent of the stress injuries were found in four regions: the Achilles tendon, the lateral femoral condyle, the patellar tendon and the medial or lateral aspects of the tibia. All responded well to treatment which consisted of physical therapy, altering or lowering the training load and taping. An increasing number of the over use injuries were found in adolescents, possibly reflecting a tendency to treat children as miniature adults, thus subjecting them to training loads exceeding the tolerance limits of their tendons and tendon insertions.

A PROSPECTIVE STUDY OF HORSE RIDING ACCIDENTS

H R Lie & U Lucht
Arhus Denmark

During 1975 a total of 203 patients were treated at the Arhus County Hospital for injuries sustained after horse riding accidents. Seventy four per cent were women and 26 per cent men. The average age was 18.7 years and teenage girls were particularly frequent victims. A total of 138 patients were injured while riding whereas 65 were injured by the horse before or after riding.

The accidents resulted in 231 injuries of which 72 per cent included soft tissue injury while 28 per cent were fractures. The majority of fractures were in the upper extremity. Eighty seven per cent of the patients were treated as outpatients and 13 per cent were admitted to the hospital. In contrast to some earlier reports it is concluded that the majority of injuries following horse riding accidents are rather insignificant. Adequate headgear would lessen the severity of several head injuries. It is

believed that it is possible to reduce the number of accidents by better instruction of beginners.

MEASUREMENTS OF THE UPTAKE OF STRONTIUM 85 FOR THE DIAGNOSIS OF STRESS FRACTURES IN THE TIBIA Ails Westlin & Bo Wendeborg Malmo Sweden

Thirty five athletes with pain in the medial aspect of the lower leg were investigated for possible stress fractures by measuring the uptake of Strontium 85. Eight of these patients had a normal uptake in the tibia and did not show any radiological signs of stress fracture, seven had distinctly localised increased uptake which corresponded to the radiological finding of a stress fracture. In the remaining 20 patients the uptake of Strontium 85 was increased along the entire tibial diaphysis. None of the latter group had any radiological signs of fracture.

The first group probably consists of patients with pain unrelated to bony structures. The second was classified as cases with stress fractures, two cases in this group had no radiological signs of fracture at the time of the uptake measurement but the diagnosis became evident later on.

The findings in the third group may be interpreted in several ways. Either these are cases with tibial stress fractures already radiologically healed which is conceivable since these cases were usually measured later in the course. Another possibility is that we have here a separate clinical entity in which the increased uptake is caused by a periosteal reaction—tibial periostitis.

FASCIOTOMY FOR TREATMENT OF LOWER LIMB PAIN IN ATHLETES

Ails Westlin & Bo Wendeborg
Malmo Sweden

Pain in the lower leg is a common symptom in athletes, particularly in runners. Those athletes who have the symptom seem to have in common that they employ muscles in the tibial posterior compartment and particularly the flexor muscles extensively. Upon the assumption that hypertrophy of the muscles by an increased pressure in the closed compartment may cause distension of the fascia, attachment to the tibia, with ensuing pain, we have operated upon 31 cases with recurring or chronic symptoms by dividing longitudinally the fascia of the posterior compartment. At follow up 23 \pm 15 months after operation 23 cases out of the 31 studied were completely free of symptoms, five were improved and three unchanged. Twenty one

patients had resumed their sporting activities completely whereas eight had decreased their activity as far as track training was concerned. Two patients had given up their sport although they gave reasons other than lower limb pain for this decision.

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TREATMENT OF MUSCLE RUPTURES

Sten Otto Liljedahl

Linköping, Sweden

Partial and total ruptures of muscles usually occur in runners and members of various team sports. Muscle ruptures are divided into two groups: ruptures by distension and ruptures by compression. Compression ruptures are most common in the deep layers of the thigh muscles and the lower leg. The diagnosis is made by clinical examination, X-ray and electromyography. Compression ruptures can be confused with soft tissue tumours. The differential diagnosis is made by fine needle biopsy. In one of the cases a false aneurysm and in another a liposarcoma simulated a compression rupture. Both cases were correctly diagnosed and treated.

Small ruptures are treated conservatively. Larger ruptures with a large haematoma should be operated on. The haematoma is evacuated and the ruptured muscle tissue sutured. Distension ruptures may safely be operated on after several months. In some of these cases no spontaneous healing of the rupture has been observed in spite of the operation having been performed after 6 months.

DYNAMIC ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION OF THE KNEE JOINT

A. Solonen & M. Vastamäki

Helsinki, Finland

A dynamic anterior cruciate ligament was constructed in 40 patients with a traumatic lesion of the ligament. In 15 cases it was a sports injury. The patients had 75 ligament lesions in all. The most common combination found in 21 cases was rupture of the anterior cruciate and tibial collateral ligaments.

Twenty-five patients had been operated on previously 31 times because of the same knee injury. Twenty-four patients had a lesion of a semilunar cartilage.

The tendon of the gracilis muscle was cut off at the insertion and led through the joint along the normal course of the anterior cruciate ligament and through a bony tunnel from the eminentia intercondylarea tibiae to the front surface of the bone where it was fixed. The postoperative immobilization time was 6 weeks.

The results were estimated on an average 2 years after the operation. The result was excellent or good in 23 cases, fair in 12 cases and in 5 cases the function of the joint was

‘a dynamic
wall
method is a

good alternative to be considered when planning treatment of patients with anterior cruciate ligament lesion of the knee joint.

END RESULTS OF SURGICAL TREATMENT OF IRISH INJURIES TO THE MEDIAL COLLATERAL LIGAMENTS OF THE KNEE

O. J. Fasting

Sonderborg, Denmark

The results of primary suture within 2 weeks after trauma were analysed on the basis of a follow up of 24 patients, 2 to 10 years after treatment. Sixteen patients were more than 40 years old. Only five had sustained their injuries during sport. Sixteen had injured the medial meniscus and undergone meniscectomy. The distribution into different groups according to subjective complaints, good, ‘fair’ or ‘poor’ was based on written answers to definite questions in a questionnaire. All patients underwent a physical and roentgenological examination.

Eight patients had no complaints at all and the others complained to varying degrees. The result was good in 12, ‘fair’ in 8 and ‘poor’ in 4. Slight instability was found in 8 cases but seemed to have had no influence on the result. Only one had instability due to non union of the ligament and the result was ‘poor’. Crepitation in the joint was found in eight cases and four cases had slight radiological osteoarthritis. Twelve cases had patellar arthralgias, four with local tenderness but the influence on the complaints was slight.

The results indicate that rupture of the medial collateral ligament of the knee should be treated with suture and a stable ligament can be obtained without grafting. The unsatisfactory results were mostly due to factors other than stability of the ligament.

III. ARTHROSIS IN KNEE INJURY

Per-Frik Riklund

Malmö, Sweden

Out of 276 consecutive knee injuries I am arthrosis was found in 106. In those cases who did not have hemiarthrosis there was only one serious knee injury whereas more than half of the cases with hemiarthrosis had fracture or total ligamentary rupture. Of the hemiarthrosis cases half of those with direct trauma had fracture. Those with a knee distortion injury sustained a fracture in only a few cases whereas partial or total ligamentary ruptures were common. Cases with hemiarthrosis and trauma that could not be clearly defined had fractures as well as total ligamentary ruptures. Also all the patellar dislocations were found in this group. It is proposed that with knowledge of the type of trauma after puncture of the joint in suspected cases and roentgen examination of those with hemiarthrosis, a group of patients can be distinguished who have hemiarthrosis.

after a joint distortion or after a less well defined trauma who need further investigation such as stability tests under anesthesia in order to exclude total ligamentary ruptures

KNEE INJURY RATE IN FOOTBALL PLAYERS AND IN THE POPULATION AT LARGE

A. Roos & G. B. J. Andersson
Göteborg, Sweden

One hundred male football players (soccer) chosen at random among retired and active players in divisions 1-4 were studied together with 108 males in the same age group (30-40 years) chosen to represent the male population of Göteborg, Sweden. Physical activity, previous injuries and diseases were explored. A clinical investigation including objective studies of lateral stability and X-ray studies of the knee joints was carried out.

Sixty five per cent of the football players had sustained an injury complained of present difficulties or had pathological findings at the time of investigation. In the population as a whole the corresponding figure was 34 per cent and when football players in this group were excluded 24 per cent. Injuries to the menisci and medial collateral ligaments were the most frequent. Twenty nine per cent of the football players had sustained lesions of the menisci and 16 per cent lesions of the ligaments. In the population the percentages were six and four respectively and when football players were excluded four and two.

Complaints were few in this age group. Clinical instability was present in 8 per cent of all those investigated, in 38 per cent of subjects with previous injuries and in 44 per cent of subjects operated on for meniscus lesions. Osteoarthritis with reduced joint space medially was found in four knees.

MINISCECTOMY: A 10 YEAR FOLLOW UP OF 150 ATHLETES

S. Sonne Holm & C. Ahn & I. Fledelius
Gentofte, Denmark

The object was to elucidate the consequences for an athlete of injury to and removal of the meniscus and the social cost of meniscal injuries sustained during sports activities.

The study included 154 meniscectomized patients who had sustained their injury while playing sports. Three per cent were lost to follow up. The median age at operation was 24 years. More than half the injuries had occurred during football games. The median follow up period was 4 years (range 2-11). Patients with a short follow up period (≤ 47 months)

had received a more intensive physical training than had those with a long follow up period (altered regime in the Unit). However this entailed no change in the number of lost working days (median 30 days).

Seven per cent had a poor subjective result. Twenty eight per cent had given up sport or had been obliged to restrict their athletic activities because of the meniscectomy. The most common complaints were pain on weight bearing, a sensation of instability, and intermittent effusion into the knee. Among patients with a short follow up period 19 per cent had radiological osteoarthritis as compared with 27 per cent among those with a long follow up period (AS). There was no correlation with the subjective complaints. Fairbank's changes (flattening of the femoral condyle, formation of marginal osteophytes on the tibial condyle) correlated positively with the subjective complaints and with osteoarthritis.

Hospital expenses and production loss per patient were calculated to amount to about 13 600 kroner (1975 prices).

INJURIES IN NORWEGIAN FOOTBALL PLAYERS: A FIVE YEAR INSURANCE MATERIAL

Asbjørn Roos & Svein Nilsson
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All Norwegian football players are covered by insurance through the Norwegian Football Association. No team is allowed to play obligatory matches until the insurance premium has been paid.

Football injuries are registered by the football association. 3616 injuries from the period 1970-1974 have been analyzed. First division clubs seem to have a higher injury rate per club than clubs in other divisions but they also have more players and spend more time playing football. Adult players have an injury rate five times higher than adolescents. Fifty two per cent of the total number of injuries are located in the lower extremities. Fractures represent 42 per cent of the injuries. Fractures of the leg amount to 18 per cent of the injuries, 25 per cent of the compensation money and 30 per cent of the number of days lost from work. The insurance company paid 15 million Nkr to the injured players during the period.

91 500 days lost from work were registered but this is a minimum figure since usually only injuries resulting in more than 14 days sick leave were registered.

RUPTURE OF THE LATERAL LIGAMENTS OF THE ANKLE JOINT IN ATHLETES OPERATIVE VERSUS NON-OPERATIVE TREATMENT

H. Ennéus, O. Ginnerup & H. Gregersen
Aalborg, Denmark

Two series of patients with ankle sprains were compiled from two accident services in Aalborg. In one, arthrography was used and the torn ligaments were sutured, in the other the sprains were non-operatively treated.

In the surgical material 40 per cent were athletes and soldiers, the mean age was lower, and men dominated. In the conservative series 20 per cent were athletes, the mean age was higher and there was no sex difference.

At the review it appeared that 39 out of 41 sutured cases had regained full athletic activity, 32 with unlimited athletic activity had no complaints, while 7 had slight discomfort but full activity. Of the 23 non-sutured cases, 20 had regained full athletic activities, but 9 had slight discomfort.

CLINICAL, ROENTGENOLOGICAL AND SOCIAL CONSEQUENCES OF RUPTURE OF THE LATERAL LIGAMENT OF THE ANKLE

H. Hansen, V. Damholt & N. B. Termansen
Odense, Denmark

149 patients (95 men and 54 women) with rupture of the lateral ligament of the ankle were followed up with an observation time from 3 to 6 years, the average being 4.2 years. The average age of the material was 26.7 years. The diagnosis was based on an inversion stress radiograph showing a difference of more than 6° in talar tilt between the injured and uninjured side. The treatment was plaster of Paris (4-6 weeks) in 130 cases, elastic bandage in 14 and operation in five cases.

Work and sport were responsible for 62 per cent of the ruptures. 20 per cent had residual symptoms at follow-up, mainly functional instability, but only 2.7 per cent had severe symptoms. Plaster of Paris and elastic bandage treatment gave equal results.

We found no connection between the degree of talar tilt immediately after the ligament rupture and the residual symptoms. There was no connection between the talar tilt at follow-up and residual symptoms. Ninety-two of the patients were sportsmen, 46 football players. Twenty per cent of the football players had to give up football. Other sports were not affected. The ability to work was not affected.

ISOMETRIC STRENGTH MEASUREMENTS OF THE CALF MUSCLE IN 30 YOUNG, NORMAL SOLDIERS AND IN 146 PATIENTS TREATED CONSERVATIVELY FOR RUPTURE OF THE LATERAL LIGAMENT OF THE ANKLE

V. Damholt, N. B. Termansen & H. Hansen
Odense, Denmark

In 30 normal, young soldiers there was no statistically significant difference in strength between dominant and non-dominant legs, but a significant difference in strength was found in favour of the right leg in relation to the left leg. The difference was slight, less than 5 per cent, and without any clinical consequence. There was no correlation whatever between isometric strength and circumference of the calf.

In 146 patients, treated conservatively for rupture of the lateral ligaments of the ankle, there was reduced strength in the affected legs. The difference was slight, about 5 per cent, but statistically significant. In 27 cases with residual symptoms after 4 years of observation there was a greater difference between the affected and unaffected legs, about 7 per cent. Also the unaffected legs had a reduced strength, indicating asthenia in the legs of patients with residual symptoms after rupture of the ligaments of the ankle. There was no correlation between strength and circumference of the calf muscle.

THE EFFECT OF OESTRADIOL ON BONE METABOLISM

Norvald Langeland
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Castrated female rats were treated with different doses of oestradiol, and the collagen metabolism in bone was studied *in vivo* and *in vitro*. The results were compared to the findings in normal uncastrated and castrated untreated animals.

Castrated animals had the highest collagen resorption rate and the highest collagen synthesis rate. Most of the treated groups did not differ significantly from normal controls in any respect. Oestradiol had no effect on collagen metabolism in bone of hypophysectomized rats. In castrated thyroparathyroidectomized animals oestradiol had approximately the same effect as in castrated controls. PTH added *in vitro* produced an elevated collagen resorption rate, while oestradiol added *in vitro* had no influence on this effect.

EFFECT OF INDOMETHACIN ON FRACTURE HEALING IN RATS

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The healing of closed standardized mid diaphyseal left femoral fractures was studied in 124 male adolescent albino rats divided into two weight matched groups given indomethacin 2 mg/kg/day and placebo, respectively. The first dose was given immediately after each fracture was made. Immediate weight bearing was allowed without fixation. Isolated femur callus specimens were subjected to radiological examination and mechanical strength testing on days 6, 9, 12, 18 and 24 after fracture. Eight fractures were studied histologically on days 9, 12, 18 and 24.

In the control animals the fractures healed within 18 to 24 days. In contrast, indomethacin 2 mg/kg/day given orally seriously impaired fracture healing.

ELECTRICAL STIMULATION OF OSTEOGENESIS IN TWO CASES OF CONGENITAL PSEUDARTHROSIS OF THE TIBIA

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The two 4 year old patients with congenital pseudarthrosis of the tibia had both been operated on twice previously without lasting healing when in 1973, as an alternative to amputation we started treatment with electrical stimulation. We used—with some modifications—the method developed by Jørgensen (1972).

After closed correction of the angular deformity, an external fixation frame was applied to which the stimulator was attached. The bone segments served as electrodes, the one next to the pseudarthrosis as the cathode. The stimulator delivered monophasic current pulses with pulse amplitude of 30 μ A, pulse duration 0.5 s and frequency 1 Hz.

The boy W.A. was treated with electrical stimulation for two periods of time. The pseudarthrosis was considered healed after the first period of 45 months. Two months later he got a spontaneous fracture in spite of wearing a long leg brace. This fracture healed radiographically in 6 weeks and clinically after 3 months of treatment. The girl J.P. was treated with electrical

stimulation for 12 weeks and for the girl 7 weeks. The advantages of this method are 1) the effective and light external fixation as compared to a plaster cast, 2) the possibility of stimulat-

ing 24 hours a day, 3) the possibility of free movement during stimulation time without confining the patient to bed or to any apparatus and 4) the minimal discomfort for the patient.

Jørgensen, T. E. (1972) *Acta orthop scand* 43, 421-437.

EXPERIMENTAL TRANSPLANTATION OF OSTEOCHONDRAL ARTICULAR FRAGMENT A PRELIMINARY REPORT

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In the treatment of osteochondritis dissecans of the knee the loosened osteochondral fragment can be fixed to its bed using thin autogenous cortical bone pins. To test the experimental basis for this operation, a study, using rabbits as experimental animals, was planned. An osteochondral defect in the articular surface of the medial femoral condyle was created with a low speed drill. The defect was reconstructed by using a local fresh autogenous osteochondral fragment, homogenous transplant or a fragment which was left free in the joint and fixed later. A stable fixation was achieved by using autogenous cortical bone pins. The results were evaluated by using clinical testing, histology, tetracycline labelling and microradiography. The preliminary results show that good stability can be achieved by using the bone pin fixation. The tip of the bone pin gradually disappears from the articular surface and is replaced by fibrous cartilaginous tissue. The remodelling in the osteochondral fragment occurs over a long period. Good anatomical reconstruction of the articular surface ensures the best operative results. The experimental observations correlate with the clinical experiences.

OSTEOCHONDRITIS DISSECANS DRILLING AND BONE PEGGING

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In addition to internal fixation using stainless steel nails we have gained some experience of bone pegging of osteochondritic fragments in the knee (Lindholm & Pyllkkanen 1974).

Sixteen patients with a mean age of 20 years, suffering from an osteochondritis dissecans lesion in the femoral condyle, were operated on. In all cases the fragment was totally or partially connected to the weight bearing surface of the joint and appeared at site (12 cases), connected with a stylos (3 cases) or as a loose body (1 case).

Measures were modified with respect to the pathological situation of the fragment. In some

cases spongy bone was transplanted to the bed of the fragment. Holes were drilled through the fragment, and cortical pins obtained from the upper tibia were used for fixation in some of them.

All patients were followed up for an average of 4 years after grafting, 16 years being the longest period. All fragments united after an average of 4 months. A resorption process was recognized in the distal ends of the pins. Slight osteoarthritic changes were observed in one patient. Nine patients were symptom free, whereas the others sometimes noted slight tenderness in the joint. They all walked normally, one had a slight recurrent hydrops, and six a quadriiceps atrophy of about 1-2 cm. A small deterioration of movement was recorded in three knees. According to the subjective symptoms and the clinical re-examination, including X-rays, the follow-up results were classified as excellent in 5, good in 8 and fair in 3 cases. No poor results were noted.

Iindholm, S. & Pylkkinen, P. (1974) *Acta chir scand* 140

POROUS CERAMICS AS A BONE SUBSTITUTE IN THE MEDIAL CONDYLE OF THE TIBIA

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A new porous ceramic material consisting of Al_2O_3 (99 per cent) and CaO, MgO and SiO₂ (1 per cent) was tested for possible use as a bone substitute in regions mainly exposed to compressive forces. The pore size varied from 100 μ to 1000 μ , the compressive strength of the material was, on average, 27 MN/m².

The porous ceramics were implanted into the medial condyle of the tibia in adult sheep and left in position for 3, 10 and 12 months. The operated tibia was removed at sacrifice, and the results were evaluated by radiography, microradiography and transmitted light microscopy. The short term implants were also studied by scanning electron microscopy.

At 3 months the implants were found to be bound to the adjacent bone by ingrowth of bony tissue, in some regions to a depth of 2-3 mm. In the long term observations no signs of loosening or collapse of the implants were seen. The maximal depth of bone invasion was slightly increased being 3-4 mm. Some ossification was still taking place. The ceramics were well tolerated, however, some foreign body cells were seen.

Based on the experimental results a clinical trial has been started with porous ceramics as a bone substitute in compression fractures of the tibial condyles. The reinforced ceramics are under development in order to produce a ceramic material more suitable for prosthetic devices.

1. FRACTURE REPAIR AFTER RIGID PLATE FIXATION WITH AND WITHOUT COMPRESSION

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Experimental transverse osteotomy through both mid tibial shafts was stabilized in 52 rabbits with a six-hole dynamic compression plate (ASIF). On the right tibia axial compression was applied to the plate, whereas the left tibia of the same animal was plated without concomitant compression. In addition both mid tibial shafts were plated in a similar way in 50 rabbits without transverse osteotomy of the bone. Specimens of bone under the plate were investigated radiologically, histologically and by fluorescence microscopy.

Fracture union was achieved uniformly within 12 weeks, regardless of the use of compression. Primary healing of the osteotomy gap could be observed, characterized by a negligible amount of periosteal callus, enlargement of the Haversian canals, appearance of cutter heads in the bone and formation of new bone in the resorption canals traversing the bone transection. Porotic transformation was a common feature both in osteotomized and intact bone causing cancellous transformation of the cortex, subendosteal resorption and thinning of the cortex. The magnitude of porotic changes were the same in bones plated with compression and without compression.

The results indicate that rigid plate fixation induces porotic changes in the cortical bone and that axial compression applied to the plate does not have any additional beneficial or untoward effect on the rate and mode of fracture repair.

BIOMECHANICAL EVALUATION OF FRACTURE HEALING AFTER RIGID PLATE FIXATION

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Helsinki, Finland

The repair of experimental transverse osteotomies through the midshaft of the tibiofibular bone was analysed in rabbits by microradiography, histology and measurement of the torque capacity of the bone. In 52 animals the right and the left tibiofibular bone was osteotomized and stabilized with a 6-hole dynamic compression plate (ASIF). On the right side compression osteosynthesis was made, whereas on the left side the plate was attached to the bone without axial compression. The animals were sacrificed from 1 to 24 weeks after the operation and the tibiofibular bones tested to breaking point in a torsion machine. Samples

of bone from the osteotomy site and adjacent areas were additionally microradiographed and studied histologically

The torque capacity of the bone increased gradually from the third week after the operation. The osteotomy united on both sides within 6 weeks after which the torque capacity equalled that of the adjacent bone. Increasing porotic changes were observed however in the bone under the plate. Due to these structural changes the torque capacity data obtained remained subnormal throughout the experiment.

The results indicate that rigid plate fixation of a transected tubular bone provides conditions for swift primary healing of the fracture gap, that axial compression added to the metallic implant has no significant beneficial effect on the mode of repair or on the torque capacity of the injured bone and that rigid plates induce structural changes in the cortical bone which adversely affect the torque capacity of the operated bone after union between the fragments has been achieved.

EXPERIMENTAL OSTEOARTHRITIS IN THE RABBIT KNEE JOINT

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The arthrotic like changes in the rabbit knee joint following resection of the crucial ligament were studied. Thirty five animals were operated upon including five where only the medial meniscus was removed as a control. Histological investigations including microradiography were performed on undecalcified and decalcified specimens. In all animals scintigraphic recordings with radioactive fluorine and technicium polyphosphate were made once or several times and in some cases microangiographic investigations with perfusion of micropaque were performed. The earliest changes consisted of deficient metachromatic staining of the cartilage. This was followed by fibrillation and formation of cell clusters. About 1½ months after the operation changes in the subchondral bone appeared with hyperaemia and formation of osteophytes through penetration of vessels into the cartilage. Scintigraphic results indicated that hyperaemia reaches a maximal value about 3 months after the operation and then diminishes despite further development of the arthrotic changes. In the control animals only slight arthrotic changes appeared and the uptake of radioactive indicators was less pronounced.

FRACTURES OF THE FEMUR IN YOUNG CHILDREN

Ulf Stungard

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The degree of anteversion in the femoral neck was radiographically measured in eight adults who at the ages of 1½ to 3½ years had sustained dislocated fractures of the shaft of the femur. All had been treated with adhesive plaster traction applied vertically to the injured leg. One patient suffering from osteogenesis imperfecta had been treated three times in this way for repeated fractures of the same femur. At the follow up investigation radiographic measurement of the anteversion of the femoral neck revealed that the difference between the unaffected and the previously injured femur did not in any case exceed 9°. The results indicate that adhesive plaster traction applied only to the affected leg is sufficient treatment for fractures of the femur in children under 3 years of age.

EPIPHYSEAL GROWTH AS A CORRECTING FACTOR OF DEFORMITY

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Spontaneous correction of post traumatic deformity of a growing long bone is a clinical fact but the mechanism of this process and the factors influencing it are not known in detail. The authors have so far been able to demonstrate that correction of position subsequent to experimentally produced deformity takes place to a considerable extent through epiphyseal growth. By changing the experimental method so that a fixed point in the diaphysis permitted exact measurement of the direction of the axis the role of epiphyseal correction could be calculated separately.

A valgus osteotomy was created in the legs of 20 young dogs and fixed with bent plates. From radiographs taken at intervals of 2 weeks the epiphyseal and axial angles were measured. It was found that the axial angles corrected rapidly during the first 60 days and more slowly towards the end of the period of study. 160 days. The epiphyseal angle which was zero in the beginning increased gradually and the average correction during the 160-day period was $12.5 \pm 0.3^\circ$.

Some animals were given tetracycline 10 to 20 days before death. Results of calculations made from these specimens agreed exactly with the radiological measurements. When these results were compared with the total correction of the deformity it could be concluded that the epiphyseal correction accounted for roughly half of the total correction. Some other factors are

certainly involved in the process, but their role in the correction is so far unclear

PSUDARTHIROSIS OF THE SCAPHOID BONE

Lasse Kvarnes

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The late results of treatment in 58 patients with pseudarthrosis of the scaphoid bone were analysed. Eleven patients were immobilised using plaster of paris eight patients had a radiocarpal arthrodesis and 39 patients were treated by transplantation of autogenous bone or by compression osteosynthesis.

Re examination approximately 5½ years later revealed a good clinical and radiological result in 88 per cent of the patients treated by compression osteosynthesis or autogenous bone grafts. Among the conservatively treated patients the result was successful in 62 per cent.

A third of the patients still had a pseudarthrosis but many of these reported a reduction in subjective complaints.

HIP SCANNING IN PATIENTS WITH INTRACAPSULAR FRACTURE OF THE FEMORAL NECK

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The series included 22 patients (17 women and 5 men) with an average age of 73.5 years. The fractures were divided into 12 subcapital and 10 transcervical fractures. There was no difference in femoral head activity between the subcapital and the transcervical fractures. However there was an increased activity in the caput femoris in cases with poor fracture alignment and this difference increased at the 3 month scanogram.

FRACTURE OF THE FEMORAL NECK—A SOCIO MEDICAL PROBLEM

O Odegård & G Unsgård

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Out of 878 patients treated for femoral neck fracture during the period 1970 to 1974 675 cases have been analyzed with regard to their social background as related to length of stay in hospital, functional result of treatment and rehabilitation.

The youngest patient was 8 years old the oldest one 100 years the mean age was 71. The majority of cases belonged to the age group 70–79 years. Seventy seven per cent of the patients were brought in from their homes only very few came from old people's homes and the rest from nursing homes and geriatric wards.

The usual treatment is plate nailing but femoral head prostheses have been used increasingly in the treatment of displaced medial femoral neck fractures in patients more than 70 years old.

On the whole men were outnumbered 3:1 by women as regards incidence. However in the younger age group the proportion of men was relatively larger, while over 70 years the proportion of women increased rapidly. Married men had a shorter hospital stay than married women but no other difference in length of hospitalization related to marital status could be encountered.

Seventy nine per cent of patients below 60 could walk without any aid 6 months after injury but only 26 per cent of patients over 60 could do this.

LOCAL CHEMICAL TRAUMATIZATION OF BONE CEMENT

Iars Linder

Göteborg, Sweden

It is known that methyl methacrylate monomer leaks from polymerizing bone cement. As the monomer is cytotoxic a local tissue injury can be expected.

By intravital microscopy in the hamster's cheek pouch it was shown that monomer leakage caused severe, localized and irreversible microvascular changes.

Small cylinders of cement were then inserted through 3.6 mm drill holes on the proximal medial side of the rabbit tibia. One tibia received cement in the doughy state and the other received already polymerized cement. The cement volumes were so small that no significant temperature rise took place.

Observation times were 10, 20, 30 and 70 days and methods of analysis were histology, microangiography, microradiography and fluorochrome labelling.

No difference in the tissue response to the test and control implants was seen. A 100–300 micron necrosis was seen round both implant types and during the course of the experiment new bone formation took place. It is concluded that in this experimental model the monomer leakage causes less tissue injury than the already minimized surgical trauma.

^{99m}Tc PYROPHOSPHATE SCINTIGRAPHY IN LOOSENING OF TOTAL HIP JOINT REPLACEMENT

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Oslo, Norway

Scintigraphy was performed on 30 hips more than 1 year after Weber total hip joint replace-

ment. 10 mCi ^{99m}Tc pyrophosphate was administered iv 4 hours before scintigraphy, using a gamma camera connected to a computer unit. The radioactivity was calculated both as a count index, comparing hip activity with normal bone activity in the lumbar spine, and subjectively from the gamma camera picture.

An increased activity around a component of the replacement correlated well with the clinical and radiological signs of loosening and with the operative findings in 26 cases reoperated upon. However, there were also cases with false negative as well as false positive findings at the scintigraphy.

Phosphate complexes labelled with ^{99m}Tc have many advantages compared with the formerly used agents such as ^{85}Sr , ^{90}Sr and ^{18}F , and though there are differences in biochemical behaviour between these agents they seem to give similar clinical information. The method can be useful in differential diagnosis of complaints after total hip joint replacement. The interpretation of the scintigraphy is difficult and the degree of uptake of the tracer is not conclusive but it can be used as another objective sign and as a complement to clinical and radiological findings.

MECHANICAL LOOSENING OF THE CHARNLEY STEM PROSTHESES

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Between 1968-1972 altogether 331 Charnley hip replacements were performed. Of these 69 hips had infection or loosening of the acetabular prosthesis. Out of the remaining 262 hips, observed for at least 1 year 83 (29 per cent) showed radiological signs of mechanical loosening. A radiolucent zone 3-12 mm wide, along the lateral edge of the stem appeared between 1-70 months postoperatively. Insufficient cement fixation at the calcar level as well as under the distal end of the prosthesis was significantly more frequent in cases with loosening. Loosening was significantly more frequent in men than in women and in younger and heavier as compared with older and leaner patients. Only half of the patients with loose stems had weight bearing pain and it is suggested that the radiological signs of loosening precede the clinical symptoms and that the proportion of patients with symptoms may increase with time. A sufficient amount of cement at the level of the femoral calcar and below the end of the prosthesis is of importance in preventing loosening. Also a varus position should be avoided.

FRACTURE OF THE CHARNLEY STEM PROSTHESES

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Malmö and Stockholm, Sweden

Since the Charnley total hip prosthesis was introduced in Sweden in 1967, 10 fractures of the stem prosthesis have been recorded. The fractures were noticed 14-62 (40 ± 15) months after surgery and were always preceded by radiographic signs of loosening. Nine occurred in males and one in a female patient. These patients were heavier than average but did not deviate in age. In only one patient was the contra lateral hip normal. Five of the fractures were overlooked initially but were found when the radiograms were reviewed. Eight of the fractured stems were in a varus position, two in a neutral position and only one in valgus. It is concluded that heavy male patients with the prosthesis in varus and with a poor proximal and a rigid distal cement fixation are predisposed to this complication.

RESULTS OF REVISION OPERATIONS OF LOOSENED AND INFECTED TOTAL HIP PROSTHESES

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In 1967-1973, 545 McKeel Farrar total hip replacements were performed. A revision operation was necessary in 38 cases. Four hips operated on originally in other hospitals were included in the series. Reapplication was done in 34 patients and excision of the prosthesis in eight infected cases. The reason for reoperation was loosening in 35, recurrent dislocation in two, perforation of the femoral cortex by the stem and malpositioning of the stem with a fracture of the proximal femur, each in one case. Previous operations were important causative factors as regards loosening. A deep infection was the cause of loosening in 12, trauma in nine, malpositioning of the prosthesis in six, other factors (cobalt allergy, spontaneous fractures, non matching parts of the prosthesis) in five, and unknown factors in six hips. The acetabular part loosened in 30 patients, between the bone and the cement in every case. The femoral part loosened with the cement in five and without the cement in 15 patients. If the prosthesis loosened at the time the patient began to have pain on weight bearing, this took place immediately after the operation in seven and during the following year in 11 cases. In the course of time loosening occurred less frequently.

The results were evaluated according to the system of Merle d'Aubigné & Postel. Twenty-one hips were classified as good or fair and 13 as

poor. Relatively good results were achieved when the cause of loosening was trauma or malpositioning of the prosthesis (12 good or fair, 6 poor results). Poor results were achieved with infected or dislocated hips. Our experience of the use of a cement mixed with gentamycin and massive antibiotic treatment in the reapplication is limited so far. Without these precautions a simple excision is indicated in infected hips.

CONGENITAL DISLOCATION OF THE HIP

Nis Fredensborg

Malmö Sweden

In the city of Malmö, 58 759 newborn children were examined for congenital dislocation of the hip during the years 1956-1972. In 548 children the diagnosis was made within 48 hours. In four children the condition was not noticed initially. This is extremely few but in accordance with the findings of other investigators.

In order to investigate the late results of treatment, 111 children treated with the von Rosen splint during the years 1956-1964 were re-examined. Clinically all were normal. Radiologically the general appearance was found to deviate in two children. In one hip the femoral head and neck were slightly enlarged as the result of early avascular necrosis and in one hip the acetabular roof was somewhat steep. Otherwise, acetabular development (measured as the CE angle) and the roundness of the femoral head (measured as the spherical index) were identical in treated children and in a control group of normal children with the same age and sex distribution.

Thus all or almost all children with congenital dislocation of the hip can be diagnosed at birth. If correctly treated a completely normal development of the hip can be expected.

THE LOAD ON THE HIP JOINT—PAUWELS THFORY

H. Glstrup

Stege, Denmark

The pressure on the caput under normal conditions in the normal hip joint, and in hip joints affected by coxa valga and coxa vara has been reviewed.

The following symptoms are characteristic of dysplasia of the hip: low back pain radiating to the hips, and pain in the adductor muscles and pedes anserinae.

Physical examination demonstrates hypermobility in the hips, tenderness on palpation posteriorly, laterally and anteriorly over the hip joint and tenderness of the adductor muscle and pedes anserinae.

Pauwels' technique endeavours to obtain better conditions of load in the hip joint thus preventing pain and osteoarthritis.

COXA VALGA TRFATTED BY VARISATION OSTEOTOMY AD MODUM PAUWELS

H. Glstrup

Stege, Denmark

Pauwels' technique has been modified to avoid hip plaster. A wedge of approximately 20° is excised between trochanter major and minor, the base medial anterior, the apex lateral posterior. The osteotomy is fixed with a child's nail and Hubbard's plate by means of 3-4 screws.

67 hips have been operated upon in 54 patients, 21-63 years of age. One died 6 weeks after the operation due to pulmonary embolism and two later of unrelated disease.

The subjective condition at follow up was excellent and good 40, fair 11, poor 5. The clinical condition at follow up was excellent and good 40, fair 8, poor 3. Radiographic examination of the 67 hips demonstrated excellent and good 57, fair 5, poor 11.

The longest observation period was 13 years. Long term observation ought to be 20-40 years.

DISLOCATION OF THE HIP IN MYELOMENINGOCELE

Cato Hellum

Oslo, Norway

The main reason for hip dislocation in myelomeningocele is muscular imbalance. This is especially liable to occur at level L₃-L₄. At this level there are active hip flexors and adductors, and paralysed extensors and abductors. Treatment aims at restoring muscular balance. This can be done by transferring muscles to trochanter major *ad modum* Sharrard. Forty three hips (29 patients) have been operated on in this way over the last 10 years.

The results were as follows: the caput in a good position in 16 hips, improvement but dysplasia/subluxation in 11 hips, failure (luxated as before) in 13 hips and in three hips the observation time was less than 6 months.

The results are mediocre if considered from a purely dislocation of the hip point of view. However, in this severely handicapped group of patients the following points should be emphasized. All patients have major paresis and gluteal insufficiency. All use splints and crutches. None has pain. Most important are the contractures found both in dislocated as well as in nondislocated hips. Thus, hip dislocation is of relatively little importance. Moreover, these pa-

titants have paralyzed legs, pressure sores, urinary incontinence, threatening hydrocephalus and social problems. They constantly require follow up or treatment.

flapsoas transfer should be done at an early stage, preferably within 1 year later, nothing more than the correction of contractures is advocated.

BONE SCINTIGRAPHY IN CALVE LEGG PERTHES' DISEASE

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L. Hertzberg & K. F. Nakken
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MgTe pyrophosphate was used to study circulation and metabolic activity in the femoral

minor changes, the scintigraphic picture disclosed reduced activity in parts of the femoral head. Later in the course of the disease, areas were found with increased activity, and in the final stage a normal distribution of radioactivity was observed.

The method seems helpful in the diagnosis and in the study of the course of CLP.

FEMORAL OSTEOTOMY IN COXA PLANA

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The radiographic results after femoral de-rotation and varisation osteotomy in coxa plana were evaluated in 47 hips. These results were compared with those obtained after conservative treatment (Thomas' splint) in 45 hips. The material was grouped according to the primary degree of necrosis of the epiphysis (Catterall 1972).

The evaluation of the epiphyseal and joint surface quotients showed that no differences in

* α , β , γ , δ are parameters and the primary degree of necrosis.

The influence of type of treatment, age, sex, side and primary degree of necrosis on the results derived from a general assessment of the radiographs (Table 1), was evaluated by stepwise regression analysis. This analysis showed that the degree of primary necrosis was highly correlated to the results ($P < 0.001$). A weak correlation was found to age ($0.05 < P < 0.01$). No correlation existed between the results and type of treatment, sex or side.

Table 1. Results derived from a general assessment of the radiographs

	Osteotomy Degree of necrosis			
	1	2	3	4
Good	100%	35%		
Fair		61%	50%	43%
Poor		4%	50%	57%
No of cases	2	26	12	7

	Thomas' splint Degree of necrosis			
	1	2	3	4
Good	100%	44%		
Fair		56%	67%	33%
Poor			33%	67%
No of cases	8	16	12	9

ARTERIAL INJURIES CAUSED BY BLUNT TRAUMA OF THE EXTREMITIES ASPECTS OF DIAGNOSIS AND TREATMENT
Tor Nierlon & Åke Hjelmstedt
Uppsala, Sweden

The purpose of this report based on 25 "orthopaedic vascular cases" is to emphasize the importance of early recognition of ischaemia in cases of blunt non penetrating trauma to the extremities. Arterial spasm without damage to the arterial wall is extremely rare. The attitude of wait and hope for spontaneous improvement is dangerous. Treatment with sympathetic block is a waste of time. Preoperative arteriography is useful if performed without delaying the arterial repair in traumatic arterial occlusions due to blunt trauma (compression, dislocation, fracture) rupture of the intima followed by an occluding thrombus is a frequent mechanism. The aim is to restore a pulsative arterial flow in the injured artery within 6-8 hours. Resection of the injured arterial segment and reconstruction with autogenous reversed vein graft end to end is the method of choice. If too small a resection is performed followed by direct arterial suture under tension reocclusion is apt to appear. Loss of distal pulses in the post-operative period demands immediate re-exploration. If massive swelling is present preoperatively or develops during or after surgery fasciotomy should be liberally used. In cases of fracture associated with arterial occlusion stabilization of the fracture by internal fixation or Hoffmann transfixation, before arterial re-

poor. Relatively good results were achieved when the cause of loosening was trauma or mal-positioning of the prosthesis (12 good or fair, 6 poor results). Poor results were achieved with infected or dislocated hips. Our experience of the use of a cement mixed with gentamycin and massive antibiotic treatment in the reapplication is limited so far. Without these precautions a simple excision is indicated in infected hips.

CONGENITAL DISLOCATION OF THE HIP

As Fredensborg
Malmö, Sweden

In the city of Malmö 58 759 newborn children were examined for congenital dislocation of the hip during the years 1956-1972. In 548 children the diagnosis was made within 48 hours. In four children the condition was not noticed initially. This is extremely few but in accordance with the findings of other investigators.

In order to investigate the late results of treatment, 111 children treated with the von Rosen splint during the years 1956-1964 were re-examined. Clinically all were normal. Radiologically the general appearance was found to deviate in two children. In one hip the femoral head and neck were slightly enlarged as the result of early avascular necrosis and in one hip the acetabular roof was somewhat steep. Otherwise, acetabular development (measured as the CE angle) and the roundness of the femoral head (measured as the spherical index) were identical in treated children and in a control group of normal children with the same age and sex distribution.

Thus all or almost all children with congenital dislocation of the hip can be diagnosed at birth. If correctly treated a completely normal development of the hip can be expected.

THE LOAD ON THE HIP JOINT—PAUWELS THEORY

H Glastrup
Stege, Denmark

The pressure on the caput under normal conditions in the normal hip joint, and in hip joints affected by coxa valga and coxa vara has been reviewed.

The following symptoms are characteristic of dysplasia of the hip: Low back pain radiating to the hips, and pain in the adductor muscles and pedes anserinae.

Physical examination demonstrates hypermobility in the hips, tenderness on palpation posteriorly laterally and anteriorly over the hip joint and tenderness of the adductor muscle and pedes anserinae.

Pauwels' technique endeavours to obtain better conditions of load in the hip joint thus preventing pain and osteoarthritis.

COXA VALGA TREATED BY VARIATION OSTEOTOMY AD MODUM PAUWELS

H Glastrup
Stege, Denmark

Pauwels' technique has been modified to avoid hip plaster. A wedge of approximately 20° is excised between trochanter major and minor the base medial anterior, the apex lateral posterior. The osteotomy is fixed with a children's nail and Hubbard's plate by means of 3-4 screws.

67 hips have been operated upon in 54 patients, 21-63 years of age. One died 6 weeks after the operation due to pulmonary embolism and two later of unrelated disease.

The subjective condition at follow up was excellent and good 40, fair 6, poor 5. The clinical condition at follow up was excellent and good 40, fair 8, poor 3. Radiographic examination of the 67 hips demonstrated excellent and good 57, fair 5, poor 5.

The longest observation period was 13 years. Long term observation ought to be 20-40 years.

DISLOCATION OF THE HIP IN MYELOMENINGOCELE

Cato Hellum
Oslo, Norway

The main reason for hip dislocation in myelomeningocele is muscular imbalance. This is especially liable to occur at level L₅-L₆. At this level there are active hip flexors and adductors and paralysed extensors and abductors. Treatment aims at restoring muscular balance. This can be done by transferring m. iliopsoas to trochanter major *ad modum* Sharrard. Forty three hips (29 patients) have been operated on in this way over the last 10 years.

The results were as follows: the caput in a good position in 16 hips, improvement but dysplasia/subluxation in 11 hips, failure (luxated as before) in 13 hips and in three hips the observation time was less than 6 months.

The results are mediocre if considered from a purely dislocation of the hip point of view. However, in this severely handicapped group of patients the following points should be emphasized: All patients have major paresis and gluteal insufficiency. All use splints and crutches. None has pain. Most important are the contractures found both in dislocated as well as in nondislocated hips. Thus, hip dislocation is of relatively little importance. Moreover these pa-

Illoponas transfer should be done at an early stage preferably within 1 year Later nothing more than the correction of contractures is advocated

BONE SCINTIGRAPHY IN
CALVE LEGG PERTHES DISEASE.
O J Fasting N Longeland I Bjerkreim
L Hertzsenberg & K F Bakken
Oslo Norway

In the early stage when X ray showed only minor changes the scintigraphic picture disclosed reduced activity in parts of the femoral head. Later in the course of the disease areas were found with increased activity and in the final stage a normal distribution of radioactivity was observed.

The method seems helpful in the diagnosis and in the study of the course of CLP.

*S. Friberg B Lundius T Persson B Tullberg &
J Aström
Umeå Sweden*

The radiographic results after femoral de rotation and varisation osteotomy in coxa plana were evaluated in 47 hips. These results were compared with those obtained after conservative treatment (Thomas splint) in 45 hips. The material was grouped according to the primary degree of necrosis of the epiphysis (Catterall) 1972.

The evaluation of the epiphyseal and joint surface quotients showed that no differences in

and these two parameters and the primary degree of necrosis

The influence of type of treatment, age, sex and primary degree of necrosis on the results, derived from a general assessment of the radiographs (Table 1) was evaluated by stepwise regression analysis. This analysis showed that the degree of primary necrosis was highly correlated to the results ($P < 0.001$). A weak correlation was found to age ($0.05 < P < 0.01$). No correlation existed between the results and type of treatment, sex or side.

	Osteotomy Degree of necrosis			
	1	2	3	4
Good	100%	35%		
Fair		61%	50%	43%
Poor		4%	50%	57%
No. of cases	2	26	12	7

	Thomas' splint			
	Degree of necrosis			
	1	2	3	4
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Poor			33%	51%
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pair, has advantages. Saving the limb from permanent damage can be achieved by early arterial restoration and subfascial decompression. Apart from the extent and level of injury, time lag is the most critical single factor. Injured extremities should be carefully observed as regards distal circulatory status and function.

ATLANTO-AXIAL INTERLAMINAR FUSION

A. Harry Sorensen & Jakob Husby

Odense, Denmark

At the departments of neurosurgery and orthopaedic surgery in Odense, 36 patients have had atlanto axial interlaminar fusion in the period November 1966 to April 1975, carried out as a team effort between the neurosurgeon and the orthopaedic surgeon and with a specially developed technique. Specially shaped bone grafts from the iliac crest with grooves for the two laminae and a graft for the right and the left side are fixed with wire.

Twenty one patients had a fracture of the dens axis, five of them with pseudoarthrosis. Ten had atlanto axial instability caused by rheumatoid arthritis and seven a horizontal instability with a distance of 12 mm from the dens to the anterior arc of the atlas. Five had a vertical dislocation with the apex of the dens 8 mm cranial to foramen magnum. Eight had medullary symptoms. Two patients had odontoid with trauma and instability, and three had other lesions. All fusions were solid at follow up at least 1 year after the operation. All fractures had healed except one. Great relief from symptoms was achieved with a minimum of restriction of movement of the cervical spine.

OCCIPITOCERVICAL AND ATLANTOAXIAL FUSION IN CHILDREN

S. Riiopuu

Helsinki, Finland

This material consists of four cases, two with congenital deformity and two with a traumatic aetiology. The age at the beginning of symptoms was 7-9 years and the time between the beginning of symptoms and operation was 5-10 months. Indications for operation were tetraparesis (one patient), inability to open the mouth and painful neck (one patient) and painful torticollis with restricted movement of the neck (two patients). Both patients with a traumatic lesion had a fixed rotary atlantoaxial luxation.

The operation was performed in skull traction. Three patients were treated with occipitocervical and one with atlantoaxial fusion. The post-operative treatment consisted of skull traction

for 4-6 weeks followed by a brace for 8 weeks. Fusion of the intended area was achieved in all cases.

The time of follow-up was from 2 to 3 years. All patients were free of subjective symptoms and pursued normal activities. The posture was almost normal in all. The movements were moderately restricted in one patient with severe atlantoaxial luxation and tetraparesis before operation. In the other three the flexion extension and rotation were restricted by 10-20 per cent and the lateral bending by slightly more.

It is concluded that occipitocervical and atlantoaxial fusion in the age group 7-10 years is a safe procedure with little risk and surprisingly little restriction of movement.

RECURRENT POSTERIOR SHOULDER DISLOCATION TREATED BY THE TRANSPOSITION OF PECTORALIS MINOR TO THE ANTERIOR BICIPITAL RIDGE

Arne Ruglveit

Oslo, Norway

Results indicate that the treatment of recurrent posterior shoulder dislocation has generally been less successful than that of the corresponding anterior dislocations. The need for a better operative procedure is therefore evident. From a functional viewpoint, transposition of pectoralis minor from the coracoid process to the proximal portion of the anterior bicipital ridge should have a favourable effect in counteracting the tendency for a posterior dislocation. The transposed muscle will exert a force directed antero-medially on the humerus opposite to the direction of dislocation. In addition on progressive internal rotation of the shoulder joint it will act with increasing effect as an external rotator, a role that is decidedly beneficial in this case since internal rotation is one component of the shoulder movement known to provoke a posterior dislocation.

The author has used this method for treatment of recurrent posterior shoulder dislocation in four cases. Two of these were traumatic in origin while two were habitual in nature. Observation time was from 6 months to 3 years. The results were good in all cases with no recurrence of the dislocation in any of the patients. The method is extremely simple and the author cannot find any previous reports of its use for treating recurrent posterior dislocations.

NEEDLE ARTHROSCOPY UNDER LOCAL ANAESTHESIA

K. Buring & F. Lund
Malmö Sweden

Arthroscopy under general anaesthesia is being used with increasing frequency as a routine method to establish the diagnosis after knee trauma. This may cause an increased burden on the facilities of the operating theatre. Sports medicine is an area where it is most important to establish a fast and correct diagnosis and needle arthroscopy under local anaesthesia is of great value. In 72 patients arthroscopies were performed with 17 mm or 22 mm needles and after gaining initial experience with the technique good visualization of the knee pathology was obtained. Multiple puncture using anterolateral posterolateral and posteromedial approaches has added valuable information

more rare conditions: 1) entrapment of the ilioinguinal nerve; 2) entrapment of the femoral nerve; 3) atypical hernias of the abdominal wall visualized by herniography.

In the first instance excessive training of the abdominal muscles by sit ups and straight leg rising may cause strangulation of the ilioinguinal nerve in its zigzag course through the abdominal wall. When a conservative approach fails symptoms are relieved by exploration. The pain distribution often mimics that of an adductor tendinitis. In the second instance three patients with long standing pain in the groin and weakness of the thigh during activity (soccer or ballet dancing) have been explored and strangulation of the lateral branches of the

ULNAR NEUROPATHY AT THE ELBOW

H. Reikerd
Islo, Norway

During the period 1961-1975 31 men and 24 women were treated for ulnar nerve palsy at Kronprinsesse Märthas Institut, Oslo. The age range was from 16 to 78 years. Thirty-four nerves on the right arm and 27 on the left were operated on with anterior transposition.

The neuropathy was secondary to trauma or disease at the elbow in 35 cases and primary with a normal elbow in 26 cases. At operation it was found that the neuropathy was due to fibrous compression in 36 per cent and to hypermobility in 21 per cent. In 43 per cent there were no macroscopic reasons for neuropathy.

The result in 51 patients in the mean 5.2 years after the operation was excellent in 47 per cent, good in 30 per cent, unchanged in 12 per cent and poor in 11 per cent. The result was independent of duration of symptoms before the operation and independent of the surgical findings at operation. The result was the same whether the nerve at the transposition was placed intramuscularly or subcutaneously.

INGUINAL PAIN IN ATHLETES

A. Buring
Malmö Sweden

Inguinal pain, sometimes with femoral radiation, is a frequent complaint in a sports clinic. Often the underlying cause may be an adductor tendinitis or a partial rupture of the quadriceps muscle and does not pose any major diagnostic problem. From a differential diagnostic standpoint our interest has been focused on three

more rare conditions: 1) entrapment of the ilioinguinal nerve; 2) entrapment of the femoral nerve; 3) atypical hernias of the abdominal wall visualized by herniography. Postoperative contrast media was introduced intraperitoneally (by a technique of Åke Gullmo, M.D., Helsingborg, Sweden). A direct relation to a tear of the abdominal transversus was noted in two cases.

MORTON'S METATARSALGIA—A FOLLOW UP STUDY OF OPERATED PATIENTS

E. Larsson
Göteborg, Sweden

The material comprised 46 patients operated upon for Morton's metatarsalgia in the period 1966-1970. Four patients had been operated bilaterally. The results were evaluated at least 6 months postoperatively (1/3 9 years) and in 40 patients after more than 1 year. The results are based on a review of the records, answers to a questionnaire and follow up examinations in cases with persistent or recurrent discomfort of some importance.

Six patients had been reoperated upon, three of whom were considered cured after reoperation. One had too short an observation time. A total of 9 out of the 50 feet had discomfort of some importance. Five out of nine had characteristic pain and were considered for reoperation. Four of these five had been operated upon under local anaesthesia.

Recurrence after operation seems to occur to a considerable extent. Reoperation can cure and should be considered in patients with recurrent discomforting Morton's pain. Detailed symptom analysis is needed for correct preoperative diagnosis. A thorough excision of the neuroma is probably of great importance for good therapeutic results. General anaesthesia and tourniquet is recommended. Pathoanatomical diagnosis is recommended to verify the diagnosis.

CHONDROCALCINOSIS AS A SECONDARY PHENOMENON

Bjarne Lindén

Malmö, Sweden

The frequency of radio opaque deposits in joints and semilunar cartilages—chondrocalcinosis—was studied in various conditions. In normal knee joints the frequency was about 1 per cent. In patients treated for osteochondritis dissecans in the femoral condyles in childhood the frequency of chondrocalcinosis was not increased above normal. However, in no less than 26 out of 41 patients, operated on in adult age for osteochondritis dissecans, chondrocalcinosis was found at a radiological follow up 25–55 years later. The same follow-up of cases operated on for torn semilunar cartilages yielded 14 cases of chondrocalcinosis out of 41 patients. In patients with gonarthrosis no chondrocalcinosis could be found in the initial radiogram, the one that gave the diagnosis. However, 10–18 years later 1/5 had radiological signs of chondrocalcinosis.

THE BLOOD ALCOHOL CONCENTRATION AMONG TRAFFIC CASUALTIES

Jørgen Høgh & Inger Guldholt

Århus, Denmark

Among 5,904 consecutive acute injuries over a 3 month period traffic accidents were respon-

sible for 339. On arrival at the casualty department a blood sample was requested from all traffic injured persons for the measurement of alcohol concentration. Some refused to attend the investigation and we have excluded all cases in which the blood sample was taken more than 2 hours after the accident. The final material then consisted of 200 drivers and 53 passengers and pedestrians.

The investigation showed a positive alcohol reaction in 34.6 per cent. Of the drivers 15.5 per cent had more than 0.1 per cent alcohol in their blood. The 15- to 19 year olds formed the greatest risk group but the maximal influence of alcohol in accidents was in a 10 year older age group. Alcohol related accidents took place first and foremost during leisure time. Of the male drivers 25 per cent had a more than 0.1 per cent blood alcohol content but no female drivers reached that level. Of the drivers who sustained accidents between 9.30 p.m. and 3.30 a.m., 61 per cent had more than a 0.1 per cent blood alcohol content, whereas in the daytime only 8 per cent had this level. The police had only registered 25 per cent of the slight injuries and 42 per cent of the more severe injuries. Therefore, the police and in that way official statistics were only acquainted with 22 per cent of accident drivers having had more than 0.1 per cent alcohol in the blood.

PROCEEDINGS OF THE SWEDISH ORTHOPAEDIC ASSOCIATION

EDITOR BO ■ NILSSON

Lund, May 20-21, 1976

ARTHIROPLASTY OF THE KNEE

A Ahlberg & B Lindén

Malmö

One hundred and thirty nine cases of total knee replacement were re investigated. Improvement was recorded in 86 per cent of the osteoarthritis and 94 per cent of the rheumatoid cases. The range of motion increased or remained unchanged in the osteoarthritis cases but was always improved in the rheumatoid cases. Knee extension was improved particularly in the rheumatoid cases. Five cases of mechanical loosening and two of infection were recorded.

A Ahlberg & B Lindén

Gothenburg

Results were presented of 11 knee arthroplasties using the Freeman Swanson knee prosthesis. Thirty two patients had rheumatoid arthritis, 8 had gonarthrosis and 3 were operated on bilaterally. All patients were studied preoperatively and postoperatively at fixed intervals of time the follow up varying from 6 to 48 months. Sixty eight per cent were rated as good (pain free walking outdoors, range of motion 10° to 90°, stable and with varus or valgus deformity of less than 10°). Thirty per cent were improved and satisfied and only 2 per cent (one patient) rated as poor. The complications included 1 deep thrombosis and 2 temporary peroneal nerve paralyses. Three joints remained unstable but only one had to be re-operated on.

KNEE ARTHROPLASTY ACCORDING TO GUNSTON HULT

H Henriksson & I Hult
Stockholm

Out of 18 cases operated on with the original Gunston prosthesis 11 were improved, two

mechanical loosening and two infections were noted and dislocation or subsiding of the prosthesis was observed in three cases. The Gunston Hult modification was used in rheumatoids mostly as a double demi prosthesis whereas osteoarthritic cases were operated on mostly with a medial demi prosthetic replacement. Fifty five out of 67 patients were excellent or good, the results being slightly better in osteoarthritis. Unimproved patients usually had complications of some sort, such as subsiding in two cases, loosening in two and infection in one. Femoro patellar osteoarthritis appeared to be of little importance.

AN UNUSUAL COMPLICATION IN THE FREEMAN SWANSON PROCEDURE

G Frykman

Västerås

A 60 year-old woman with rheumatoid arthritis was operated on using the Freeman Swanson procedure. The operation succeeded technically but after 20 days instability was noted. The distal end of the femur was displaced medially in relation to the tibia. Later when instability increased the patient was re-operated on. There was a complete rupture of the medial collateral ligament in the femoral attachment and a partial rupture of the collateral ligament. The prosthesis was removed and replaced by a hinge prosthesis with good results.

THE HYPOPERFUSION SYNDROME IN KNEE ARTHROPLASTY

H Fdeldt & L Lidgren
Lund

Hypotension and hypoxaemia have been reported to occur as perioperative complications in intramedullary implantation of endoprostheses in the knee and the hip. It has been claimed that these complications are caused by the insertion of cement and prosthesis into the marrow cavity. Preliminary results of operations

with the Marmor procedure indicate that such complications may be seen even if the marrow cavity is not involved

SCINTIMETRY AS A DIAGNOSTIC MEANS IN SUSPECTED INFECTION OF TOTAL ARTHROPLASTY OF THE KNEE JOINT

G Jonsson I Lidgren & I O Sjöstrand
Lund

A high infection rate (50 per cent) was recorded in 15 patients with osteoarthritis operated on with the Guépar total hinge prosthesis. Pre-, per- and postoperative antibiotic prophylaxis markedly reduced the infection rate. Scintimetry could be used in diagnosing the infection and in assessing the effect of antibiotic treatment.

PROSPECTIVE SURVEY OF ENDOPROSTHETIC ARTHROPLASTY OF THE KNEE IN SWEDEN

G Bauer, M Grönlund & A Lindstrand
Lund

All departments of orthopaedic surgery in Sweden, a total of 34 units, have agreed to participate in a collaborative prospective study of endoprosthesis arthroplasty of the knee. In each case a form will be completed on discharge and submitted to a central agency together with copies of pre- and postoperative X-rays. On the original form early complications will be reported. After discharge, all complications will be reported. The agency will report at regular intervals on types of complications with relation to diagnostic groups and types of endoprostheses. As the number of knee arthroplasties performed in Sweden increase, the total number of operations reported should reach about 10 000 in 6 to 7 years.

BONE CHANGES AND BONE HEALING AFTER RIGID OSTEOSYNTHESIS

P Ståhl
Helsinki

The application of a rigid plate on diaphyseal bone in rabbits caused a change of cortical bone into trabecular. Because of osteoclast activity a considerable porosity occurred in about 3 weeks. The resorption cysts increased and after 12 weeks a confluence of the cysts was noted. The torque breaking strength decreased by 40 per cent. The bone grew wider because of subperiosteal apposition. A similar pattern was seen after osteotomy or fracture. Healing usually occurred after 11 weeks. Compression did not speed the healing process.

SECONDARY OPERATION OF FRACTURE OF THE ANKLE JOINT

S Olerud
Stockholm

Shortening and outward rotation of the fibula is the most common cause of osteoarthritis after ankle fractures. Late reconstruction of the talo-fibular joint can be obtained by clearing the syndesmosis of fibrous tissue as well as lengthening and derotating the fibula after osteotomy. This procedure also tightens the anterior fibulo-talar ligament. Dorsiflexion is usually improved.

SCINTIMETRY OF PATELLAR OSTEOMYELITIS

H Hallin & A Nylen
Falun

A case of patellar osteomyelitis in a young boy was described. A scintimetric study with technetium Tc99m revealed a decrease of the uptake in the affected patella at an early stage, the uptake later on being increased above normal and finally becoming normal. This early decrease in uptake may be related to a relative avascularity of the patella during the first acute phase.

SCINTIMETRIC STUDY OF OSTEOCHONDROITIS DISSECANS IN THE FEMORAL CONDYLES

B Lindén
Malmö

The uptake of ^{86}Sr was studied in 12 cases of osteochondritis dissecans in the femoral condyles of young adult men. There was an increased local uptake of tracer close to the lesion but not in the rest of the joint. The uptake was considerably less than in localized changes due to osteoarthritis or osteonecrosis.

THIARAPUTIC ARTHROSCOPY

N Örtengren, J Gullqvist & G Hagberg
Lund

In a series of 700 arthroscopies, 40 per cent of the cases had to have arthrotomies. However, in cases of loose bodies in certain semilunar cartilage lesions and for the removal of sutures after cruciate ligament repair, arthroscopy can be used therapeutically. Loose bodies less than 4 mm can be flushed out, larger bodies may be removed using a stone basket. With this technique, bodies larger than 2 x 1 cm were removed. The knee function was completely restored 3 to 4 days postoperatively with full ability to participate in competitive sports.

EXPERIENCE OF THE ACUTE MANAGEMENT OF SPINAL CORD INJURIES

(Guest lecture)

M Weiss

Konstancja, Poland

A review of 3500 spinal cord injury cases was made at the Konstancja Rehabilitation Institute in Poland. Immediate operative treatment for total paralysis with or without instability has been suggested for the last 6 years. Special springs are used to accomplish reduction and stability. In unstable fractures an autograft of iliac crest bone is used. Postero-lateral approaches can be performed after the stabilization in order to remove disc protrusions. Caution and cautions are advised in non-complete cases.

no-one knows how great the damage to the cauda equina is. Surgery decreases the risk of secondary changes. Stabilization of the fracture improves the breathing of the patient and reduces venostasis. Springs are the best devices for filling into the sphere between transverse and spinous processes.

A NEW CONTRAST AGENT FOR MYOLOGRAPHY

S Cronqvist

Lund

Ampaque is a new local water soluble contrast medium suitable for examination of the bony canal space and the whole spinal canal. No spinal anaesthesia is needed. The size of the canal can be easily evaluated and roots and root sleeves are well demonstrated offering increased diagnostic information in the cervical and lumbar regions. Adverse reactions seem to be less frequent and definitely less pronounced than with pre-existing agents. No irreversible side effects—arachnoiditis—have been recorded.

REHABILITATION OF SPINAL CORD INJURIES IN SWEDEN

A Stenram

Lund

There is a considerable risk of secondary neurological injury during the initial handling of patients with spinal cord injuries. Transportation under ideal conditions directly to a spinal cord unit is to be preferred. A helicopter flight provides less stress on the injured patient than rapid ground transportation. Surgery is indicated particularly in cases with progressive neurological injury. The Cloward operation may be useful in immobilization of the cervical

spine and at other levels surgery may also help in the early mobilization of the patient. Experimental data indicate that one should continue to try steroids in the early treatment of spinal cord injuries.

LASER IN ORTHOPAEDIC SURGERY

H Horosowski

Tel Hashomer, Israel

In laser surgery the coagulation effect is particularly useful. The laser radiation may be used in tumor surgery and joint surgery. In applying the method on Ewing sarcoma and osteogenic sarcoma the cutting and the devitalizing effect of the laser beam is used. The hemostatic effect is its greatest advantage in joint surgery. Cutting of bone with the laser beam may cause healing difficulties and compression osteosynthesis is therefore advised in such cases. The surgical procedure may be complicated with skin burns. Postoperative pain is reduced. The most important use is in tumor surgery and in hemophilia surgery. It is also valuable in arthrolysis and joint replacements but is still questionable where surgery on the fine structures is involved.

IS THERE AN INCREASING RISK OF FEMORAL NECK FRACTURE?

K Öbman

Malmö

The total number of femoral neck fractures is increasing in the city of Malmö in spite of a fairly constant population. Until about 1968 the incidence and risk of fracture had also increased. After that time however the risk has increased only in the age group over 80. However, owing to the population distribution of the city there is still a continuing rise in the total number.

ENDER NAILING OF TROCHANTERIC FRACTURES

M Nilsson

Stockholm

Eight hundred and fifty hips have been operated on since 1971. The experience is positive with few complications (4 per cent). The patients were mobilized on the first day; the mean hospitalization time being 26 days.

RE OSTEOSYNTHESIS OF FEMORAL NECK FRACTURE

C. Zetterberg, L. Irsam & G. Andersson
Cölbeburg

Over five years, 10 per cent of more than 500 cases of cervical femoral neck fracture were re-

osteosynthesized. Most of the cases were of Garden's stage IV. The primary reduction had in most cases been acceptable. The indications were penetrating or sliding nail with or without fracture dislocation. Only 22 per cent of the reosteosynthesized cases healed whereas the remainder showed signs of pseudarthrosis or necrosis all without relation to the fracture type.

WHEN IS A CONTROL VISIT NEEDED AFTER HIP FRACTURE IN THE ELDERLY?

E Liedberg
Lund

Almost 250 patients with hip fractures are treated in Lund every year. From 1972 to 1975 34 patients were treated for complications. Only in one third of the cases were the complications suspected at regular follow up examinations. Patients with complications have severe pain and need medical advice. Regular follow up with radiograms is recommended on three occasions only: postoperatively, after 10 days and after 4 months.

SCINTIMETRIC STUDIES FOR THE EARLY DIAGNOSIS OF FEMORAL HEAD NECROSIS

G Baur, R Brummer, N Gustavsson
L I Hansson, W Mortenason & L O Sjöstrand
Lund

Eighty four patients were studied with ^{85}Sr scintimetry. Forty healed without complications. Forty four were complicated in one way or another. The uptake in the femoral head normally drops slowly after the fracture whereas those with complications maintain a significantly higher uptake. In a prospective series of 29 patients, measurements were taken with a digital step scanning technique at short intervals after surgery. During the first two months after surgery the uptake of ^{85}Sr could not predict complications whereas after 4 months the uptake was correlated to the clinical course and to complications.

FRACTURES OF THE ACETABULUM—A FOLLOW UP OF 100 PATIENTS WITH 101 FRACTURES

O Linsinger & I Goldie
Gothenburg

Out of 66 patients with central fractures 61 were treated conservatively and 5 surgically. Of the conservatively treated patients there was no central dislocation of the femoral head in 30 cases and the result for these patients was excellent—good in 90 per cent. In 15 patients with central fracture dislocation the fracture involved the inner acetabular wall and the result

for these patients was excellent—good in 87 per cent. However, in those 16 patients with fractures of the acetabular roof the result was only excellent—good in 38 per cent. Five patients were treated surgically: 1 was good and 4 poor. Of 35 patients with posterior fractures 17 were treated conservatively with excellent—good results in 82 per cent. Eighteen were treated surgically with excellent—good results in 67 per cent.

FUNCTION FOLLOWING REMOVAL OF TOTAL HIP PROSTHESES

G Gudmundsson, S A Ahlgren, F Bertholdsson & I Hermansson
Skövde

Eleven patients were reviewed on average 13 years after the initial total hip implantation. The implants were all removed due to infection. Three patients were working and all patients were improved with regard to pain as compared with their initial status. Only one regretted the initial operation and none the removal of the prosthesis. Five patients experienced weight bearing pain and five experienced pain on resting. One patient grossly overweight was mostly confined to a wheelchair. Two could not walk outdoors and another four felt that the hip was unstable. Ten of the patients had healed promptly, whereas one had recurring fistula for three months. There was an average leg shortening of about four centimeters and three patients had an outward rotational malposition. Otherwise there was no fixed malposition. There was a considerable difference between active and passive range of motion. Two of the patients showed signs of mental depression needing psychiatric care.

HEMODILUTION IN TOTAL HIP REPLACEMENT SURGERY

A Ahlberg, A Nilius, B Rosberg & A Udden
Malmö

Preoperative normovolemic hemodilution using dextran 70 was studied in a controlled randomized group of patients ($n = 40$). The patients were drained of 15 litres of blood. The control group were given 0.5 litre Macrodex 6 on the day of operation and on the third postoperative day. The total blood loss was not increased by hemodilution. In the hemodilution cases most of the blood was replaced by the patient's own. Pulmonary emboli detected by lung scanning were more frequent in the control group and one patient died of pulmonary embolization. There were no serious complications in the hemodilution group. The technique markedly reduced the need and risks of bank blood.

and possibly reduced the rate of postoperative pulmonary emboli

QUADRI LATERAL CAST BRACE IN FEMORAL SHAFT FRACTURES

*E Mattsson
Lund*

Six fresh femoral shaft fractures and five femoral shaft fractures with delayed union were treated with a functional walking plaster cast. The fractures were located on the two lower thirds of the femoral shaft. The bracing was preceded by traction for about 2 months. A brace moulded on the thigh was then used for another 2 to 4 months. Within 7 months all cases were healed. In fresh cases the range of knee motion became normal and there was no shortening of the leg. In the cases of delayed union on the treatment was in 2 cases combined with a pseudarthrosis operation. One infected case took 15 months to heal otherwise healing was observed to take place within 6 months. There were no complications with this treatment.

COMPARISON OF MENISCECTOMY IN INPATIENTS AND OUTPATIENTS

*A Stenström B Hagstedt & P Ljung
Lund*

Half of the patients were operated on as outpatients half were admitted to hospital for surgery. There were no differences in the preoperative signs and symptoms in the two groups. At the follow up there was no difference in the number of postoperative outpatient visits nor was there any difference in results between the two groups.

THE POLYDACTYL PTERYGIUM SYNDROME

*L I Hansson A Jonsson A Stenström & A C Thorgren
Lund*

A 74 year-old woman with this syndrome was

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one of 10 siblings and the father and paternal grandmother showed signs of the syndrome. This is an autosomal dominant hereditary syndrome with incomplete penetrance and expression and with deformities such as polydactyl pterygium equinus foot osseous dysplasia syndactylia, perineal webbing hypertrophy of the clitoris hypotrophy of labia and uterus hair pigmentation and growth deviations are also found. These patients develop general arthrosis and spondylosis. As in this patient a greater than normal Cx angle may be seen.

A MODIFIED OSTEOSYNTHESIS ACCORDING TO RYDELL IN EPIPHYSEOLYSIS OF THE FEMORAL HEAD

*L I Hansson A Stenström & K G Thorgren
Lund*

A Rydell nail has been modified so that the inserted nail is attached to the femoral head proximal to the growth zone. When the femoral neck grows the nail is pulled into the femur since the attachment proximal to the epiphyseal line is maintained. The method was successfully used for reoperation of cases with slipping nails as well as in fresh cases.

PSEUDARTHROSIS AFTER TIBIA OSTEOTOMY

*B Tjörnstrand B Hagstedt & B Persson
Lund*

Twelve cases with delayed union or pseudarthrosis after tibia osteotomy for gonarthrosis were re-operated on seven with resection of the pseudarthrosis reduction and Charnley compression osteosynthesis one with a hinge prosthesis and the remainder by various methods. Comparison was made between the preoperative status and the final status in these patients. With regard to pain there was improvement with regard to walking capacity there was no change. In most instances the required correction of the initial angulation deformity was obtained. The cases described here represent 3.6 per cent of the total of a series of tibia osteotomies. It is concluded that these cases should be reoperated on and that the Charnley compression instrument is useful for this purpose.

AUTOTRACTION

*S O Myrin
Taby*

Thirty seven consecutive patients with signs of herniated disc were treated by autotraction in a collapsible portable traction frame—the Spina-trac. After an average of six treatments per patient 29 recovered completely six were much improved and one somewhat improved whereas one patient with obstructive arterial disease remained unchanged. Thirty nine patients with backache without signs of disc herniation for at least one month were treated an average of five times. Thirty-one recovered completely. The frame has also been successfully used for cervical traction and hip traction.

LEFT SIDE PREDOMINANCE OF LUMBAR DISC HERNIATIONS

*E Spangfort
Huddinge*

Out of 2504 lumbar disc operations 533 per cent were left sided regardless of the sex of the patient. There was no left side predominance in cases with a negative finding at operation. The predominance was less at more cranial levels of lumbar herniation. It was not related to heavy work. The left side predominance was highest in young patients and those under the age of 40 when disc herniation is most common. This pattern was most obvious in cases with complete herniations.

AN ORTHOPAEDIC OUT PATIENT SERVICE

*H G Edeland
Molndal*

Sixteen months of experience of the work in a separate out patient service attached to an orthopaedic department was presented. In one year one surgeon treated 4397 patients, 210 of whom were operated on. The ratio of first visits to return visits was 1:1.

RADIOGRAPHIC ASSESSMENT OF DISLOCATION IN DISTAL RADIAL FRACTURES

*S Friberg & B Lundström
Umeå*

Radiography was performed in 40 wrists with fractures of the distal part of radius. The effect of moderate rotation of the wrist and various directions of the central beam on the inclination of the distal radial joint plane in the lateral view was studied. It was demonstrated that small differences in rotation of the wrist seriously altered the measured inclination of the joint plane when a perpendicular projection was used. Angulation of the central ray 15° in a proximal direction significantly increased the accuracy of the examination.

THE RADIAL TUNNEL SYNDROME

*C O Werner
Lund*

Symptoms similar to those of the tennis elbow may be caused by compression of the deep branch of the radial nerve. A series of photographs of the operative findings in selected cases was presented.

EVALUATION OF A MULTIFUNCTIONAL HAND PROSTHESIS CONTROLLED BY MYOELECTRIC PATTERNS

*P Herberts & C Almström
Gothenburg*

A promising approach to the control problem in multifunctional hand prostheses is the use of a pattern recognition technique in conjunction with a digital computer. A portable control system for operating three bidirectional movements of a hand prosthesis based on this technique has been developed and adapted to the Swedish hand prosthesis which has 24 active movements. An added advantage is that the functional pattern may be studied with the computer. The evaluation has shown that two amputees equipped with this control system were able to use all the prosthetic movements available.

EFFECT OF GROWTH HORMONE AND THYROID ON CORTICAL BONE REMODELLING AND ON LONGITUDINAL BONE GROWTH

*A Stenström, L I Hansson & K G Thorngren
Lund*

Cortical bone remodelling along the femoral diaphysis and longitudinal bone growth in the proximal tibia were determined in hypophysectomized and hormone treated hypophysectomized female rats aged 60 to 100 days with the tetracycline technique. The hypophysectomized animals showed an increased periosteal resorption and an increased endosteal growth whereas the longitudinal bone growth increased. Thyroidine increased the periosteal resorption but had no endosteal effect whereas the longitudinal growth increased.

THE FRACTURE INCIDENCE IN 87 EPILEPTICS TREATED WITH DIPHENYLDANTOINE

*A Wallöe & L Lidgren
Lund*

The fracture incidence was studied in 87 patients with epilepsy. In 7 years 34 of these patients had altogether 70 fractures, 35 of which belonged to the group of fragility fractures. Thirteen fractures occurred during epileptic seizures. Even when the latter cases were excluded the risk of fracture in epileptic patients was calculated to be six times greater than the expected rate when age and sex were taken into account.

CLEAR CELL SARCOMA OF TENDONS AND APONEUROSSES

Report of Two Cases

KARI ALITALO, PEKKA PAAVOLAINEN, KAARLE FRANSILA & VEIJO RITSILÄ

Division of Plastic Surgery, Helsinki University Central Hospital, and Department of Pathology, University of Helsinki, Finland

Two cases of clear-cell sarcoma of tendons and aponeuroses are reported. The first patient was a 19-year-old man with a tumor in the medial collateral ligament of the knee. The tumor was enucleated, and after postoperative radiotherapy a wide local excision was done. The patient was symptomless 4½ years after the operation. The other patient was a man aged 68 with a tumor between the medial malleolus and the Achilles tendon. He also received postoperative radiotherapy after enucleation. Three months later a metastasis was noticed in the ipsilateral para iliac nodes. The patient died 16 months after the operation. The histology and clinical course of the two cases are analyzed. Some integrative remarks based on earlier reports of 11 cases and the present two cases are presented.

Key words: clear-cell sarcoma, malignant tumor of tendons and aponeuroses, soft somatic tumor of the extremities.

Accepted 21.1.77

CASE REPORTS

Case 1. A 19-year-old man was admitted to hospital because of a tumor of the left knee. He gave a history of two episodes of mild trauma to the knee during his military service, 6 and 2 months prior to admission. After the second injury the knee was painful during exercise, and the patient discovered a small nodule on the medial side of the knee.

Physical examination revealed a small, firm, movable nodule on the medial side of the knee, which was thought to be a cyst of the medial meniscus. At operation in March 1977 the medial meniscus appeared normal but a nodule about 1 cm in diameter was found in the medial collateral ligament. This light brown tumor was easily enucleated. Microscopic examination revealed a clear-cell sarcoma of tendons and aponeuroses.

The operated region was treated by tele-cobalt therapy (3136 R over a period of 24 days) fol-

lowed by a wide local excision of the medial joint capsule. During this operation, no signs of tumor were noted. After 2 weeks, another dose of 3136 R for 3 weeks was given to the same area.

A radio ulcer developed on the medial aspect of the knee. The ulcer was closed with an abdominal tubed pedicle flap carried via the wrist and the right knee.

When last examined in November 1976, 4 years and 7 months after the operation, no signs of metastases or local recurrences were observed.

Case 2. The patient was a man aged 68 with a history of relapsing erysipelas on both legs. One month before surgery he observed a firm movable nodule on the dorsal aspect of his right ankle. During the following weeks the tumor grew in size, and the patient reported slight pain when walking. There was no history of trauma to the ankle.

On examination, a firm, oval, movable mass, 4 cm in diameter, was palpated beneath the skin.

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Out of 2504 lumbar disc operations 533 per cent were left sided regardless of the sex of the patient. There was no left side predominance in cases with a negative finding at operation. The predominance was less at more cranial levels of lumbar herniation. It was not related to heavy work. The left side predominance was highest in young patients and those under the age of 40 when disc herniation is most common. This pattern was most obvious in cases with complete herniations.

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Cortical bone remodelling along the femoral diaphysis and longitudinal bone growth in the proximal tibia were determined in hypophysectomized and hormone treated hypophysectomized female rats aged 60 to 105 days with the tetracycline technique. The hypophysectomized animals showed an increased periosteal resorption and an increased endosteal growth whereas the longitudinal bone growth increased. Thyroxine increased the periosteal resorption but had no endosteal effect whereas the longitudinal growth increased.

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CLEAR CELL SARCOMA OF TENDONS AND APONEUROSES

Report of Two Cases

SARI ALITALO, PEKKA PAAVOLAINEN, KAARLE FRANSILLA & VEIJO RITSILÄ

Division of Plastic Surgery, Helsinki University Central Hospital, and Department of Pathology University of Helsinki Finland

Two cases of clear-cell sarcoma of tendons and aponeuroses are reported. The first patient was a 19 year old man with a tumor in the medial collateral ligament of the knee. The tumor was enucleated and after postoperative radiotherapy a wide local excision was done. The patient was symptomless 4½ years after the operation. The other patient was a man aged 68 with a tumor between the medial malleolus and the Achilles tendon. He also received postoperative radiotherapy after enucleation. Three months later a metastasis was noticed in the ipsilateral para iliac nodes. The patient died 16 months after the operation. The histology and clinical course of the two cases are analyzed. Some integrative remarks based on earlier reports of 33 cases and the present two cases are presented.

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Accepted 21.7.77

CASE REPORTS

Case 1 A 19 year old man was admitted to hospital because of a tumor of the left knee. He gave a history of two episodes of mild trauma to the knee during his military service 6 and 2 months prior to admission. After the second injury the knee was painful during exercise and the patient discovered a small nodule on the medial side of the knee.

On examination both the function and X rays of the knee were normal. The only finding was a small tender nodule under the skin on the medial side of the knee which was thought to be a cyst of the medial meniscus. At operation in March 1972 the medial meniscus appeared normal but a nodule about 1 cm in diameter was found in the medial collateral ligament. This light brown tumor was easily enucleated. Microscopy revealed a clear-cell sarcoma of tendons and aponeuroses.

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lowed by a wide local excision of the medial joint capsule. During this operation, no signs of tumor were noted. After 2 weeks, another dose of 3136 R for 3 weeks was given to the same area.

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Case 2 The patient was a man aged 68 with a history of relapsing erysipelas on both legs. One month before surgery he observed a firm movable nodule on the dorsal aspect of his right ankle. During the following weeks the tumor grew in size, and the patient reported slight pain when walking. There was no history of trauma to the ankle.

On examination, a firm, ovoid, movable mass 4 cm in diameter, was palpated beneath the skin

of the medial calcaneal region. No destruction of bone could be demonstrated radiologically, and the function of the ankle joint was normal. Clinically the tumor was regarded as a fibroma.

An extirpation was done in June 1974. The solid, well-demarcated tumor was situated between the medial malleolus and the Achilles tendon, with no invasion of surrounding tissue. It was surrounded by dense fibrous tissue. The lesion probably originated from the Achilles tendon sheath. The tumor was light-brown colored, and the cut surface gave the impression of a benign fibroma or leiomyoma. However, the histological diagnosis was clear-cell sarcoma of tendons and aponeuroses.

Postoperative tele-cobalt therapy up to a tumor dose of 6000 R for 7 weeks was given. Three months later lymphography demonstrated metastases in the right para-iliac nodes. This was verified histologically, and after extirpation the regional nodes were treated by a feline dose of 5000 R for 2 months. Thereafter, the patient was symptomless for 9 months. He died in November 1975, 17 months after the diagnosis. At autopsy, bronchopneumonia and metastases in lungs and adrenals were found.

HISTOLOGICAL FINDINGS

The staining methods used were haematoxylin and eosin, Weigert-van Gieson, Alcian blue, Periodic acid-Schiff reaction (PAS) with and without diastase, Gomori's reticulum stain, Gomori's method for iron and Fontana method for melanin.

The microscopic examinations revealed the tumors to be non-encapsulated, but their exact relation to the surrounding tissues could not be evaluated because both tumors had been removed by enucleation. The tumors were composed of solid nests and fascicles of cells surrounded by connective tissue septa. The septa were mostly thin and delicate but sometimes the cell groups were separated by thick and dense fibrous areas (Figure 1). Reticulum fibers were seen around the cell nests, but they were scarce or absent between individual tumor cells (Figures 2 and 3). The tumor cells were either round or spindle-shaped. The nuclei were large, pale-staining and round with prominent basophilic nucleoli. In case 1, some giant cells with multiple uniform nuclei were observed. Mitotic figures were few, about 1-4 per 10 high-power fields. The cytoplasm was abundant and pale-staining, usually clear and often filled with tiny vacuoles (Figure 4). In case 2, small amounts of diastase-sensitive PAS-negative material was found in the cytoplasm of some tumor cells. No intra- or extracellular Alcian blue-positive mate-

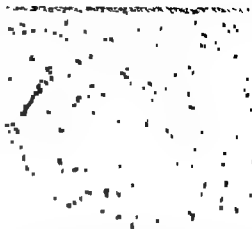


Figure 1. Clear-cell sarcoma (Case 1). The tumor is composed of solid nests of cells surrounded by delicate connective tissue septa. Also dense fibrous areas are seen between the nests (H and E, $\times 50$).



Figure 2. Clear-cell sarcoma (Case 1). Reticulum fibers surround cell nests (Gömöri's reticulum stain, $\times 50$).

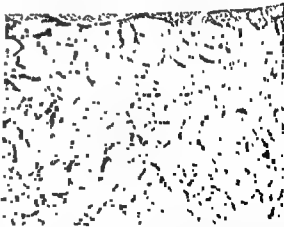


Figure 3. Clear cell sarcoma (Case 2). Both thin reticulum fibers and thicker collagenous septa surround cell nests (Gömöri's reticulum stain, $\times 50$).

rial was observed. In both cases, both intra- and extracellular iron was present, but no Fontana-positive material was found. The metastatic tumor in case 2 did not differ histologically from the primary tumor.

DISCUSSION

The two tumors presented here fulfill the histologic criteria of the clear-cell sarcoma of tendons and aponeuroses presented by Enzinger in 1965. The most important of these criteria are the typical reticulum pattern, the clear cytoplasm of the tumor cells and the large pale nuclei with a prominent nucleolus. Histologically it may be difficult to differentiate this tumor from synovial sarcoma, alveolar soft part sarcoma, chemodectoma, malignant melanoma, or metastasis from a clear-cell carcinoma. The tumors presented here did not have the pseudoglandular pattern of synovial sarcoma, nor did the cytoplasm of the tumor cells reveal PAS positive, diastase-resistant granules typical of alveolar soft part sarcoma. In chemodectoma, the septa surrounding the cell groups contain blood vessels, but these were not seen in the present cases. Fontana-positive pigment, which is usually present in malignant melanoma, was not found in these two tumors. Nor was any other tumor found in the skin or elsewhere which could have transferred metastases. Consequently the histological diagnosis made seems to be correct.

Mackenzie (1974) has described one and Bearman et al (1975) two clear-cell tumors originating from tendon which contained melanin pigment. Electron microscopy showed melanosomes in the cases described by Bearman et al. The tumors thus represented melanomas with an apparent soft tissue origin. No melanin has been mentioned in the other reported cases. In a case report by Hoffman & Carter (1973) the primary tumor showed the features of clear-cell sarcoma but in a recurrent tumor and in meta-

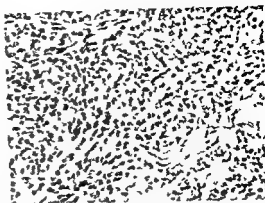


Figure 4 Clear-cell sarcoma Case 2. The nuclei are large and pale with prominent nucleoli. The cytoplasm is clear and abundant and filled with vacuoles of varying size (H and E, $\times 150$).

stases 3 years later melanin pigment was seen. It is possible that some of the cases reported represent amelanotic melanomas.

Although it is possible that clear-cell sarcoma of tendons and aponeuroses is not histogenetically a homogenous group it seems to be a rather homogenous group clinically. Therefore, some integrative remarks based on earlier reports (Bennett 1947, Guichard et al 1968, Rousselot et al 1968, Kubo 1969, Vuillard 1969, Dutra 1970, Jung et al 1970) and the present two cases are presented here (a total of 35 cases, cases with melanin pigment were not included).

The median age of the patients at diagnosis was 32 years (range 12-68 years). Males and females were equally represented (17 males, 18 females).

At the time of the first operation, all tumors were solitary. The diameter of the tumor varied from 1 to 6 cm. The topographic distribution of the primary tumor is shown in Table 1.

Metastases were observed in 18 of the 30 cases with a follow-up of at least 1 year. They were located most frequently in regional lymph nodes and lungs, also metastases in bone, liver, heart and adrenals were observed. The median interval between the first operation and

the occurrence of the first metastasis was 4 years (range 1 month to 30 years).

Clear cell sarcoma seems to be especially prone to recur, in the 30 cases with a follow-up of at least 1 year recurrences were observed in 20 cases. This may be partly explained by the rather conservative surgical treatment due to the benign, well-demarcated appearance of the tumor at operation.

Table 1 Anatomical distribution of the 35 clear cell sarcomas reported

Location	No. of patients
Lower extremity	
Planta pedis	6
Achilles tendon	4
Knee	5
Ankle	4
Patellar tendon	3
Heel	1
Buttock	1
Toe	2
Upper extremity	
Finger	5
Palm	1
Forearm	2
Triceps	1
Total	35

The mortality rate in clear cell sarcoma is high, 18 out of the 30 patients with a follow-up of at least 1 year have died. The actuarial 5-year survival rate was about 50 per cent. Although the mortality rate is high the growth of the clear-cell sarcoma seems to be rather slow. The duration of symptoms prior to the treatment was less than 1 year in 13 cases, 1 to 4 years in 11 cases and more than 5 years in 8 cases (maximum 19 years), no data were available for three patients. Three deaths from cancer occurred more than 10 years after treatment (11, 12 and 36 years later).

Thirty-two of the cases were primarily treated by local excision. For 25 patients

this was the only treatment during the first stage. This treatment was followed by radical operations in 15 cases (extensive local excisions, 9 amputations). Only 10 patients received radiotherapy. The different forms of therapy did not seem to differ in therapeutic value. However, if local excision is not adequate, recurrence is the rule. No significant differences appear between patients treated early or those treated after several recurrences.

ACKNOWLEDGMENTS

We would like to thank docent Börje Sundl MD, for his help in the preparation of this paper.

REFERENCES

- Bearman, R. W., Noe, J. & Kempson R. L. (1978) Clear-cell sarcoma with melanin pigment. *Cancer* 36 977-984.
- Bennett, G. A. (1947) Malignant neoplasms originating in synovial tissues (synovials). *J Bone Jt Surg* 20 259-291.
- Dutra, F. R. (1970) Clear cell sarcoma of tendons and aponeuroses. *Cancer* 25 942-947.
- Enzinger, J. M. (1965) Clear cell sarcoma of tendons and aponeuroses. *Cancer* 18 1181-1174.
- Guichard, A., Feroldi, J. & Lamy, M. (1968) Le sarcoma alvéolaire à cellules claires des tendons. *Ann Anat Path* 13 11-20.
- Hoffman, G. J. & Carter, M. (1973) Clear-cell sarcoma of tendons and aponeuroses with melanin. *Arch Path* 95 22-25.
- Jung, A., Kehr, P. & Vuillard, N. (1966) Le sarcoma à cellules claires des tendons et des aponeuroses. *Rev Chir Orthop* 56 553-567.
- Kubo, T. (1969) Clear cell sarcoma of patellar tendon studied by electron microscopy. *Cancer* 24 948-953.
- Mackenzie, D. H. (1974) Clear cell sarcoma of tendon and aponeuroses with melanin production. *J Path* 114 231-232.
- Rousselot, P., Weill-Boussion, M., Lefakis, P., Wetter, J. M. (1969) Le sarcoma à cellules claires des tendons et aponeuroses. *Ann Anat Path* 13 325-334.
- Vuillard, N. (1969) Contribution à l'étude des tumeurs malignes des gaines tendineuses. Le sarcoma à cellules claires. Thesis Strasbourg.

METAL SENSITIVITY IN PATIENTS TREATED FOR TIBIAL FRACTURES WITH PLATES OF STAINLESS STEEL

SE CRANERS & ULF LUCHT

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Department of Orthopaedic Surgery Aarhus Amtssygehus Aarhus, Denmark.

In three patients a local dermatitis developed 3-3½ months after tibial osteosynthesis with plates and screws of stainless steel 316 L (AO). Two of the patients had a positive patch test for chromium (and cobalt) and one for nickel. Infection was not indicated and it is suggested that the dermatitis was caused by a metallic sensitivity. The skin affection disappeared after removal of the metal.

Key words: dermatitis, metallic sensitivity, stainless steel, tibial fracture.

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Contact sensitivity to nickel, chromium and cobalt is well known although the incidence of skin sensibility to these metals in the general population is unknown. Fregert et al (1969) have tested a group of 4825 patients suspected of having various skin diseases and found the following frequencies of positive patch tests in the female/male patients: nickel 102/18 per cent, chromium 16/107 per cent and cobalt 66/74 per cent. A few cases of eczematous dermatitis caused by internal exposure to nickel have been reported (Fousserau & Augier 1966, Barranco & Solomon 1972, Pegum 1974).

The aim of the present report is to draw attention to the possibility of local dermatitis caused by metal sensitivity in patients treated for tibial fractures with implants of stainless steel.

CASE REPORTS

Case 1 A 19 year-old woman sustained an un-

and eight screws (AO) of stainless steel (Figure 1). She was mobilized with crutches without weightbearing on her left leg 8 days after the operation and the postoperative period was uncomplicated. Weightbearing was started 2 months after the operation. One month later an erythematous and infiltrated area appeared on the skin overlying the plate and at the same time local pains occurred. The roentgenograms showed no signs of reaction around the metal. An infection was suspected and 2 weeks later an incision was made. No pus was observed and no bacteria were found by culture. The erythrocyte sedimentation rate was 9 mm/1 hour. From these observations an infection seemed unlikely and some days later the metal was removed and the skin closed. Skin healing was uncomplicated without use of antibiotics and the dermatitis disappeared. The fracture healed after treatment with a plaster cast. A patch test 2 months after removal of the metal was positive for chromium and cobalt. The reaction was strongest after 96 hours without a toxic reaction.

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REFERENCES

- Bearman, R. M., Noe, J. & Kempson R. L. Clear cell sarcoma with melanin pigment. *Cancer* 36: 977-984.
- Bennett, G. A. (1947) Malignant neoplasm arising in synovial tissues (synoviosarcoma). *J Bone Jt Surg* 20: 259-291.
- Dutra, F. R. (1970) Clear cell sarcoma of tendons and aponeuroses. *Cancer* 25: 912.
- Fenzinger, F. M. (1965) Clear cell sarcoma of tendons and aponeuroses. *Cancer* 18: 1174.
- Guichard, A., Feroldi, J. & Lamy, M. Le sarcoma alvéolaire à cellules claires des tendons. *Ann Anat Path* 13: 11-20.
- Hoffman, G. J. & Carter, D. (1973) Clear cell sarcoma of tendons and aponeuroses: melanin. *Arch Path* 95: 22-25.
- Jung, A., Hehr, P. & Vuillard, N. (1969) Clear cell sarcoma of tendons and aponeuroses. *Rev Chir Orthop* 56: 51.
- Kubo, T. (1969) Clear cell sarcoma of the tendon studied by electron microscopy. *Cancer* 24: 948-953.
- Mackenzie, D. H. (1974) Clear cell sarcoma of tendons and aponeuroses with melanin pigment. *J Path* 114: 231-232.
- Rousselot, P., Weill-Boussion, M., Lefebvre, W. & Wetter, J. M. (1968) Le sarcome à cellules claires des tendons et aponeuroses. *Ann Anat Path* 13: 325-334.
- Vuillard, N. (1969) Contribution à l'étude des tumeurs malignes des gaines tendineuses. Le sarcome à cellules claires. Thesis Strasbourg.

METAL SENSITIVITY IN PATIENTS TREATED FOR TIBIAL FRACTURES WITH PLATES OF STAINLESS STEEL

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In three patients a local dermatitis developed 3-3½ months after tibial osteosynthesis with plates and screws of stainless steel 316 L (AO). Two of the patients had a positive patch test for chromium (and cobalt) and one for nickel. Infection was not indicated and it is suggested that the dermatitis was caused by a metallic sensitivity. The skin affection disappeared after removal of the metal.

Key words: dermatitis, metallic sensitivity, stainless steel, tibial fracture.

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Contact sensitivity to nickel, chromium and cobalt is well known although the incidence of skin sensitivity to these metals in the general population is unknown. Freger et al (1969) have tested a group of 4825 patients suspected of having various skin diseases and found the following frequencies of positive patch tests in the female/male patients: nickel 102/18 per cent, chromium 36/107 per cent and cobalt 66/74 per cent. A few cases of eczematous dermatitis caused by internal exposure to nickel have been reported (Fousserau & Augier 1966, Barranco & Solomon 1972, Pegum 1974).

The aim of the present report is to draw attention to the possibility of local dermatitis caused by metal sensitivity in patients treated for tibial fractures with implants of stainless steel.

CASE REPORTS

Case 1 A 19 year old woman sustained an uncomplicated fracture of the left tibia and fibula after an accident with a moped. The tibial fracture was fixed under compression using a plate and eight screws (AO) of stainless steel (Figure 1). She was mobilized with crutches without weightbearing on her left leg 8 days after the operation and the postoperative period was uncomplicated. Weightbearing was started 2 months

after the operation. The roentgenograms showed no signs of reaction around the metal. An infection was suspected and 2 weeks later an incision was made. No pus was observed and no bacteria were found by culture. The erythrocyte sedimentation rate was 9 mm/1 hour. From these observations an infection seemed unlikely and some days later the metal was removed and the skin closed. Skin healing was uncomplicated without use of antibiotics and the dermatitis disappeared. The fracture healed after treatment with a plaster cast. A patch test 2 months after removal of the metal was positive for chromium and cobalt. The reaction was strongest after 96 hours without a toxic reaction.

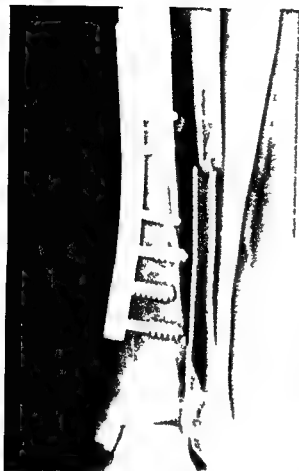


Figure 1 Case 1 Postoperative roentgenogram

Case 2 A 19 year old woman sustained an open fracture of her right tibia and fibula after a fall from a horse. The tibial fracture was fixed under compression with a plate and eight screws (AO) of stainless steel (Figure 2). The postoperative period was uncomplicated. She started walking without weightbearing on her right leg 7 days after the operation and with weightbearing after 2½ months. After 3½ months an erythematous and infiltrated area appeared on the skin overlying the plate and local pains occurred. In the following weeks the symptoms varied in intensity. They increased after a period of walking and decreased after a period of relaxation. Five months after the operation a little bulla developed in the erythematous area. No bacteria were found by culture. The roentgenograms showed no reaction around the metal. The plate and the screws were removed and the skin closed. No pus was observed around the metal and no bacteria were found by culture. The erythrocyte sedimentation rate was 7 mm/1 hour. Skin healing was uncomplicated without the use of antibiotics and the dermatitis disappeared. The fracture was treated with a plaster cast and healed without complications.

A patch test 4 months later was positive for chromium and cobalt. The reaction was strongest after 96 hours without a toxic reaction.

Case 3 The patient was a 46 year old woman who sustained an uncomplicated fracture of her right tibia and fibula after a fall from a table. The tibial fracture was fixed under compression with a plate and seven screws (AO) of stainless steel (Figure 3). The postoperative period was uncomplicated. Walking without weightbearing on the right leg was started 7 days after the operation. Three months postoperatively an erythematous and infiltrated area appeared on the skin overlying the plate and local pains occurred. In the following weeks the symptoms varied in intensity and were reduced after a period of relaxation. The roentgenograms showed no reaction around the metal. At 3½ months after the operation a bulla appeared in the erythematous area. The first cultivation for bacteria was negative but a second which was made some days later showed staphylococcus aureus. The plate end screws were removed and the skin closed. No pus was observed around the metal and no bacteria could be cultivated from the



Figure 2 Case 2 Postoperative roentgenogram



Figure 3 Case 3 Postoperative roentgenogram

surrounding tissue. The erythrocyte sedimentation rate was 19 mm/1 hour. The skin healed without antibiotics and the dermatitis disappeared. The fracture was treated with a plaster cast and healed without complications. A patch test at the time of removal of the metal was positive for nickel. The reaction was strongest after 72 hours without a toxic reaction.

None of the three patients referred to had any recognized metal hypersensitivity or eczema prior to the accident and there was no evidence of occupational exposure to metals.

METHODS

Patch test

The following solutions of metals were used: Nickel sulphate 5 per cent, potassium dichromate 0.5 per cent, cobalt chloride 2 per cent, manganese chloride 2 per cent, ferric chloride 2 per cent, sodium molybdenum 2 and 5 per cent, all with petrolatum as vehicle. The concentration of the solutions was 100 mg/ml.

Testing (Fregert et al 1969). Iron, manganese and molybdenum were used in the same concentrations as used by Geiser et al (1960).

The patch test was placed on the back just below the scapula and left for 48 hours. A reading was taken 48, 72 and 96 hours after the application. The reactions were considered positive if erythema and infiltration with or without papules or vesicles occurred.

Analysis of the implant

The stainless steel (316 L) used for the present three patients contains chromium, nickel, molybdenum, manganese, iron, carbon, silicon, sulphur and phosphorus but not cobalt.

A portion of the stainless steel was rotated for 35 days in a Ringer solution at 37.8° C. The solution was subsequently tested by atomic absorption spectrophotometry for any dissolved metal. Iron, manganese and nickel were detected but not chromium. The analysis was performed by the Division of Inorganic Chemistry, University of Aarhus, Denmark.

DISCUSSION

The three cases described are rather similar and it is strongly suggested that the skin reactions were caused by metal sensitivity and not by infection. Thus, the positive patch tests in combination with no previous known allergies and the disappearance of the skin reactions after the removal of the implant are consistent with metal sensitivity caused by the implant. The absence of bacteria after culture from the tissue around the plates, the normal sedimentation rates and the uncomplicated skin healing after the removal of the plates argue against infection.

A release of metal ions from an implant requires a corrosion of the alloy. Generally it has been believed that stainless steel implants have a high corrosion resistance. However, the following reports indicate that various metallic alloys currently in use in human beings, including stainless steel, are exposed to corrosion. Thus, Lüdinghausen et al (1970) made histological examinations in 50 cases treated by osteosynthesis with



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A release of metal ions from an implant requires a corrosion of the alloy. Generally it has been believed that stainless steel implants have a high corrosion resistance. However, the following reports indicate that various metallic alloys currently in use in human beings, including stainless steel, are exposed to corrosion. Thus, Lüdinghausen et al (1970) made histological examinations in 50 cases treated by osteosynthesis with

stainless steel (AISI 316) and found some degree of metallosis in every case from 4-36 months after surgery Ferguson et al (1960) embedded different kinds of metallic implants in the spinal muscles of albino rats for 4-6 months. In the muscles surrounding the metal they found, by spectrochemical analysis, metallic elements in concentrations which were significantly higher than in controls. For stainless steel (AISI 316) they found nickel, chromium, iron and molybdenum. Cohen (1962) tested various metals *in vitro* under cyclic stresses similar to those encountered in clinical practice. He used screws and plates and determined their weight loss after 10 million cycles. Stainless steel (AISI 316) had a higher weight loss than vitallium. The most common site for the corrosion is the junction between components of implants (Scales et al 1959, Emnéus 1961, Cohen 1962). Scales et al (1959) believe that the anaerobic condition between countersinks of screws and screw holes is a cause of the corrosion which often occurs at this location.

For the three patients in the present report the concentrations of metal ions in the tissue surrounding the implants has not been measured. When the implants were rotated in a Ringer solution we found nickel, manganese and iron but not chromium. The inability to demonstrate the last metal may be due to the conditions *in vitro* being different from those *in vivo* where cyclic stresses and changes in the oxygen tension affect the implant. The present observations that the complaints of two of the patients were reduced after a period of relaxation and increased after a period of walking are consistent with a varied release of metal ions depending on variations in cyclic stresses and blood flow.

The local dermatitis in our three patients is a delayed type (Gell & Coombs type IV) hypersensitivity (Lowney 1975).

It is not possible to know with certainty if the patients were sensitive to the metal before the implantation. This, however, was not indicated by the anamnesis and the time sequence of events rather indicates that the implants induced the sensitivity. The metal reaction in the present patients developed a relatively short time after the operation, but this may be explained by the close relationship between the implants and the skin. The two patients who had positive patch tests for cobalt were presumably sensitive to this element at the time of the operation because stainless steel does not contain cobalt. The disappearance of the dermatitis after removal of the metal is in agreement with other studies (Barranco & Solomon 1972, Fousserau & Laugier 1966).

Once acquired, specific sensitivity tends to persist but the degree of sensitivity may decline if the patient avoids contact with the specific allergen. However, after re-exposure to the primary allergen the level of the sensitivity rises rapidly, and the patient may get a new allergic reaction. It is important for the orthopaedic surgeon to be aware of this possibility, and in doubtful cases patch test the patient. Titanium may be a satisfactory substitute if a positive patch test for nickel or chromium is found.

The present report together with earlier studies (Fousserau & Laugier 1966, Barranco & Solomon 1972, Pegum 1974, Munro Ashman & Miller 1976) stress that if a skin reaction occurs some months after osteosynthesis a metal sensitization should be suspected. In the case of metal reaction the symptoms will disappear after removal of the metal which should be performed under sterile conditions to avoid a secondary infection.

REFERENCES

- Barranco, V P & Solomon, H (1972) Eczematous dermatitis from nickel *J Amer med Ass* 220 1244
- Cohen, J (1962) Corrosion testing of orthopaedic implants *J Bone Jt Surg* 44 A, 307-316
- Finnéus, H (1961) Experimental investigation of corrosion of stainless steel used in bone surgery *Acta orthop scand* 44b, 1-62
- Ferguson, A B, Laing, W G & Hodge, E S (1960) The ionization of metal implants in living tissues *J Bone Jt Surg* 42 A, 77-90
- Fousserau, J & Laugier, P (1966) Allergic eczemas from metallic foreign bodies *Trans St Johns Hosp derm Soc (Lond)* 82 220-225
- Fregert, S, Hjorth, N, Magnusson, B, Bandmann, H J, Calnan, C D, Cronin E, Walten K, Meneghini, C L, Pirtilä V & Wilkinson, D S (1969) Epidemiology of contact dermatitis *Trans St Johns Hosp derm Soc (Lond)* 85, 17-35
- Gelser, J D, Jeanneret, J P & Delacretaz, J (1960) Eczéma au ciment #1 sensibilisation au cobalt *Dermatologica (Basel)* 121, 1-7
- Lowney, E. D (1975) Contact dermatitis In *Dermatology* Vol 1 Ed Moschella, S L, Pillsbury, H M & Harley, H J p 245 W B Saunders Company, Philadelphia, London, Toronto
- Lüdinghausen, M V, Meister, P & Probst, J (1970) Metallosis after osteosynthesis *Path europ* 5 307-314
- Munro Ashman, D & Miller, A J (1976) Rejection of metal to metal prosthesis and skin sensitivity to cobalt *Contact Dermatitis* 2, 65-67
- Pegum, J S (1974) Nickel allergy *Lancet* 1, 674
- Scales, J T, Wauter, G D & Shirley, H T. (1959) Corrosion of orthopaedic implants: Screws, plates and femoral nail plates *J Bone Jt Surg* 41 B, 810-820

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- Barranco V P & Solomon H (1972) Eczematous dermatitis from nickel *J Amer med Ass* 270 1244
- Cohen J (1962) Corrosion testing of orthopaedic implants *J Bone Jt Surg* 44-A 307-316
- Emelius H (1961) Experimental investigation of corrosion of stainless steel used in bone surgery *Acta orthop scand* 44b 1-82
- Ferguson A H, Lang P H & Hodge F S (1960) The ionization of metal implants in living tissues *J Bone Jt Surg* 42 A 71-90
- Foussereau J & Laugier P (1966) Allergic eczemas from metallic foreign bodies *Trans St Johns Hosp derm Soc (Lond)* 68 220-225
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THE EFFECT OF IMPACT LOADING ON RABBIT KNEE JOINTS

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Sahlgren Hospital, Göteborg, Sweden

Fifteen mature male Whiteland rabbits received repetitive impulse loads slightly larger than body weight (4 kp) through one knee joint for periods from 1 to 6 weeks. Mechanical compression of subchondral bone cores from impacted tibiae showed progressive increased deformation under a constant force. Cartilage degeneration occurred concurrently with alterations in the mechanical properties of the subchondral bone. The cartilage degeneration may be explained by (i) the deleterious effect of repetitive mechanical compression, (ii) the decreased mechanical support of the underlying subchondral bone.

Key words subchondral bone, microfractures, fatigue, impact load as reflected light microscopy

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Despite a multitude of factors known to be responsible for the induction of both clinical and experimental degenerative joint disease, the etiology of primary osteoarthritis remains unsolved (Gardner 1966).

The attenuation across joints of forces resulting from impact loads has been shown to be a function of subchondral bone and soft tissue rather than cartilage or synovial fluid (Radin et al 1970). A current hypothesis concerning the etiology of degenerative joint disease proposes that microfractures occur in subchondral bone as a result of repetitive impact loads. These lead to subchondral bone stiffening secondary to callus formation (Radin et al 1973). This stiffening of the subchondral bone presumably reduces its shock absorbing qualities, which then predisposes the overlying cartilage to degeneration.

The purpose of this study is 1) to

produce experimental degenerative joint disease secondary to impact loading and 2) to examine the changes occurring in the affected tissues, particularly the subchondral bone.

MATERIALS AND METHODS

Loading machine

An experimental machine was designed which loaded the right knee joint of six rabbits simultaneously (Figure 1). Both legs were held in extension at the knee joint with plastic splints. The right leg of each animal was subjected to a 4 kp impulse load 56 times per minute for 1 hour daily. The frequency and amplitude of the impact load were selected so as to simulate the work of Radin et al (1973). The left knee of each animal served as a control and was not loaded.

A schematic drawing of how the cyclic impulse load was delivered is shown in Figure 2. The springs used to produce the 4 kp load were specially constructed to produce this force with 5 mm of deformation. All springs were tested

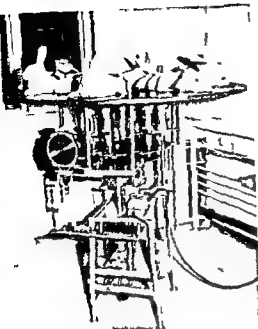


Figure 1 Six rabbits are shown in the impulse loading machine. The right leg of each rabbit received a 4 kp load 56 times per minute. The left leg was not loaded and served as a control.

for error prior to and at the completion of the experiment—this was found to be ± 1 per cent. The height of the cylinders in which the springs were housed was made adjustable to accommodate anatomical variations in the rabbits' legs.

The relationship of force input to time is depicted by a dome shaped curve (Figure 3). The impulse load of each cycle started at 0.07 sec, rose to 4 kp at 0.23 sec and then decreased to 0 kp of force at 0.49 sec. The total duration of the impulse was 0.42 sec.

The rapid rise and fall of this force-time relationship was chosen to simulate clinical stresses occurring in the human knee joint while walking (Morrison 1970).

Animal selection

Eighteen male Whitehead rabbits weighing from 2.5–3 kg were divided into six groups containing three animals each. Each group was then tested for time intervals from 1 to 6 weeks. The knee joints of all animals were X-rayed prior to testing to ensure skeletal maturity. All animals were allowed free movement in their cages except for the 1 hour of daily impact loading.

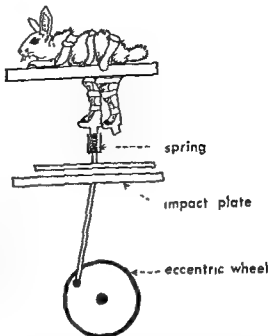


Figure 2 A schematic drawing showing how the impulse load was produced and transmitted to the right leg of each rabbit. Special springs were constructed to produce 4 kp of force with 5 mm of deformation.

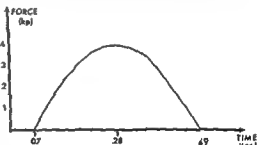


Figure 3 The dome shaped curve represents the force input into the right leg with each impulse load. This impulse load occurred 56 times per minute for 1 hour daily. The rapid rise and fall of the force input was selected to simulate joint loads which occur clinically.

Experimental procedure

A general outline of the experimental procedure followed is shown in Figure 4.

Tibial cores

At the completion of each week of loading, three animals were sacrificed and both knee

joints were disarticulated. The proximal ends of the tibiae were then placed in plastic molds to fix the sites of the cores. With a 5 mm trephine drill, under cooling irrigation, a core was removed from each medial tibial condyle. The core was then machined in a turning lathe with an optical microscope attached to ensure complete removal of all cartilage. A special chuck with a face-plate backing ensured that both surfaces of the specimen were parallel. The length of the core was 3 ± 0.05 mm.

Mechanical testing

An Alvetron testing machine compressed the tibial cores to a maximum of 1 kp of force (error ± 1 per cent). The rate of compression was 0.05 mm/min. The deformation of each core was simultaneously read in a recorder and a load deformation curve was thus obtained (Figure 5).

Each sample was measured with a micrometer (± 0.01 mm) before and after testing. The permanent deformation produced by the mechanical compression is recorded in Table 1.

All samples were stored in normal saline at room temperature prior to testing. The time interval from sacrifice of the animal to testing was approximately 6 hours.

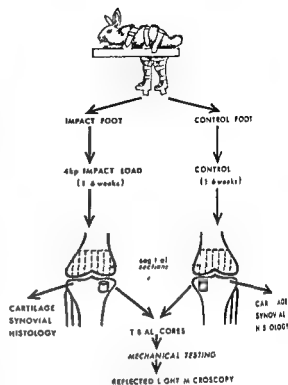


Figure 4 A schematic outline of the experimental procedure followed

Table 1 The mechanical deformation of the control and loaded tibial cores. The permanent deformation produced by mechanical compression is recorded in column 8 and is measured in microns. The higher incidence of permanent deformation occurring on the loaded as opposed to the control side should be noted.

Rabbit	1 week		2 weeks		3 weeks		4 weeks		5 weeks		6 weeks		Perm def	
	contr	load	contr	load	contr	load	contr	load	contr	load	contr	load	contr (μ)	load
1	22.4	12.6											0	0
2	25.3	28.0											0	0
3	20.0	28.0											0	0
4			13.0	29.5									0	40
5			26.0	18.0									0	0
6			22.0	24.0									0	10
7					19.5	25.0							0	10
8					21.5	22.0							0	10
9					20.5	26.0							10	10
10							16.0	22.5					10	10
11							17.0	22.5					0	0
12							27.5	40.0					0	0
13									22.5	40.0			0	10
14									15.0	22.5			0	0
15									28.0	41.0			0	0
16											17.5	22.5	0	20
17											18.0	35.0	0	20
18											18.0	35.0	0	30

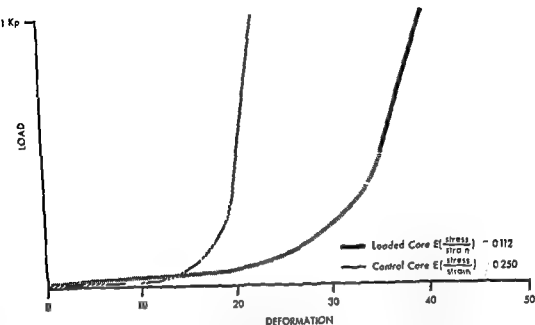


Figure 5 This is a graphic representation of the load/deformation curve obtained from the Alvetron testing machine. These curves refer to the control and impact loaded tibial cores from a rabbit subjected to 5 weeks of impact loading (see Table 1 rabbit 13). The units of deformation correspond to the squares of the actual graph paper output from the Alvetron. These can be converted to absolute values (mm) by dividing by 323. The non linear portion (broken lines) of each curve represents the seating in of the core during initial mechanical compression. The linear portion (solid line) of each curve depicts elastic deformation of the tibial cores. By calculating the slopes of these solid lines we can then compare the relative modulus of elasticity or stiffness between the impact loaded and control cores.

$$\text{Control core } E \left(\frac{\text{stress}}{\text{strain}} \right) = \text{slope} \approx \frac{1 \text{ kilopond}}{22.5 - 18.5} = 0.250$$

$$\text{Impact loaded core } E \left(\frac{\text{stress}}{\text{strain}} \right) = \text{slope} \approx \frac{1 \text{ kilopond}}{40 - 31.1} = 0.112$$

The slopes of each curve are in load/deformation units. Since each core was standardized for length and cross sectional area, these values are directly proportional to absolute stress/strain units (i.e. modulus of elasticity).

Femoral condyles

The right and left distal femurs were cut sagittally to a depth of 15 mm and a thickness of 2 mm under cooling irrigation (Figure 4).

Histology

1) *Synovium* Synovial biopsies of both knees were fixed in 4 per cent neutral formalin and then stained with hematoxylin and eosin and van Gieson.

2) *Cartilage* The lateral tibial condyles were fixed in 4 per cent neutral formalin, decalcified in Parency solution and stained with Toluidine blue at pH 0.5 and 4.0, hematoxylin and eosin and van Gieson.

3) *Tibial cores and femoral slices* These samples were first defatted in solutions of ethyl alcohol and ether. The liquid component of the bone was removed by vacuum drying. The specimens were then embedded in epoxy resin (Araldite D*) under vacuum (Luft 1961). The specimens obtained were ground with wet silica carbide paper polished and then subjected to reflected light microscopy (Pugh et al 1972).

Limitations of present study

1) *Force input* Although the cylinders were adjustable to accommodate anatomical variations

* (Araldite D Cl 230 Ciba)

in each rabbit leg, the error in force input could not be controlled to better than ± 500 g.

2) *Tibial cores* The use of plastic molds standardized the size and angle for selection of each core from the medial tibial condyle. Anatomical variations in the size of tibiae introduced an unavoidable error.

3) *Permanent deformation* The amount of permanent deformation produced by compressing the bone with 1 kp of force is recorded in Table 1 (column 8). This deformation is produced by breaking the bone. Artifactual cracks thus result from this testing procedure. However, since our criteria of a true microfracture included the demonstration of callus breaks resulting from artifact would be excluded.

RESULTS

1) Gross examination of tibial cores

The impacted tibial cores became more friable and developed a texture analogous to granular sugar as the experiment progressed. These changes were not noted on the control side.

2) Mechanical compression of tibial cores

Figure 5 is a graphic representation of the load deformation curve obtained from the Alvetron testing machine. The deformation curves refer to the control and impact loaded tibial cores from a rabbit tibia subjected to 5 weeks of impact loading. These curves allow the comparison of relative stiffness (modulus of elasticity) between an impact loaded and a control core. The modulus of elasticity of the control core is 0.250 while that of the impacted core is 0.112 (Figure 5).

No significant difference was found between the impacted and control tibial cores in the first 2 weeks of loading (Table 1). This is attributable to the minimal difference in the average deformation values between the impacted and control groups (Sign and Walsh Test Siegel 1956). In the 3, 4, and 5 week groups

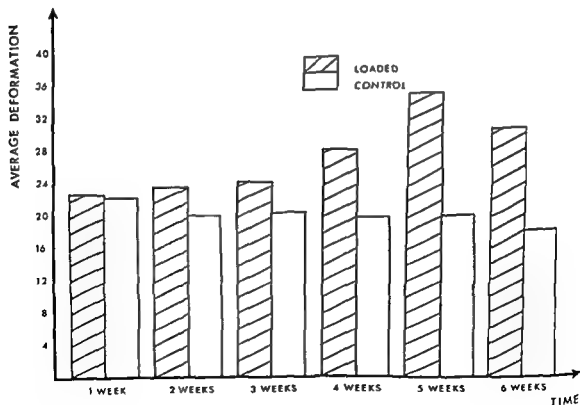


Figure 6 Bar graph showing the average mechanical deformation of the control and loaded tibial cores with time.



Figure 7 Photomicrograph of a cancellous bone trabecula subjected to reflected light microscopy ($\times 50$). This specimen is taken from a 3 week impacted tibial core. The arrows show artifactual cracks produced either by the machining or the mechanical testing of the specimen. Note the absence of callus. A denotes the epoxy resin in which the specimen is embedded. The dark diagonal lines seen crossing the specimen are artifacts produced during polishing.

there were statistically significant differences between the impacted cores on a 10 per cent level.

The mechanical deformations of the control and tested tibial cores at weekly intervals are also shown in Table 1. In all rabbits (except for rabbits one and five) the deformation observed in the loaded cores exceeded that in the control group. As the cancellous bone became more deformable the mechanical deformation increased (Figure 5).

The average deformation of the tibial cores progressively increased over the 8 week period (Figure 6). The average deformation for the 1, 3, and 6 week impacted group was 22.9, 24.3, and 30.8 units.

1) Permanent deformation

The amount of permanent deformation in the tibial cores following the 1 kp of mechanical force is recorded in Table 1 (column 8). Permanent deformation oc-

curred in 12 of the 36 cores tested. Of these, ten occurred in the loaded tibial cores, the remaining two in the control cores.

4) Reflected light microscopy of tibial cores

Reflected light microscopy demonstrated numerous artifactual cracks to be present in all tibial cores. These occurred either in preparation of cores or during mechanical compression.

A cancellous core from a 3 week impacted tibia is shown in Figure 7. The crack in the trabecula is indicative of an artifact because it lacks callus formation. A photograph of an impacted tibial core from a 5 week animal is shown in Figure 8. This crack is suggestive of a healing microfracture in that it displays periosteal swelling. The lack of cellular activity is related to the preparation of the specimen.

In general the number of artifacts

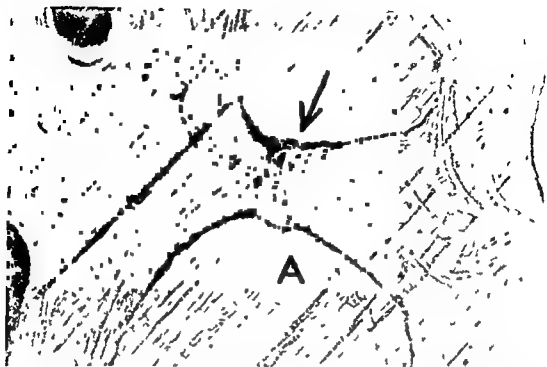


Figure 8 Photomicrograph of cancellous bone taken from a 5 week impacted tibial core (reflected light microscopy $\times 42$). The fatigue fracture depicted by the arrow shows periosteal reaction indicative of callus formation. Note the lack of displacement at the fracture site.

tural cracks occurring in the control tibial cores remained relatively constant throughout the experiment. The impacted cores, however, tended to show an increase in artifactual cracks as the experiment progressed. Trabecular fractures associated with periosteal reaction as depicted in Figure 8 were absent from the control cores and did not appear in any of the impacted cores until 2 weeks of loading. It must be stressed, however, that their occurrence was rare and did not seem to increase with the duration of loading. Of all the specimens examined, only two examples of the microfracture shown were found.

5) Reflected light microscopy of femoral slices

The frequency of artifactual cracks on the control side remained constant while the loaded side showed a progressive increase of artifacts with time. However, no evidence of fractures associated with callus formation were seen in any of these specimens.

6) Histology of synovial membrane

A Gross After the first week of impulse loading the impacted knees developed synovial effusions, which were progressive with time and associated with gradual atrophy of the synovial membrane and steady thickening of the joint capsule.

B Microscopic examination The normal synovial membrane has a loose connective tissue stroma (Figure 9) and the first changes in the experimental synovial membrane occurred in this stroma. The loose stroma was gradually replaced by cellular connective tissue with collagen fibers (Figure 10). A progressive increase in capillary vessels in the synovial villi occurred and in some areas there was hyperplasia of the synovial epithelium. In all impact loaded rabbits, by the 6 week period, foreign body giant cells were seen in the synovial stroma and pericapsular tissue (Figure 11). Van Kossa stain revealed that some of these giant cells contained calcium.

The synovial membrane of the control

side remained normal both grossly and microscopically

7) Histology of articular cartilage

A Gross The impacted articular cartilage of the tibia and femur showed a gradual loss of the glistening, shiny, blue white appearance of normal cartilage. Changes were noted by the end of the first week of testing and there was a gradual progression to a non glistening, yellow, fibrillated surface accompanied in the later stages with lifting of the joint margins

No changes were noted in the control knees

B Microscopic examination Histological examination with hematoxylin and eosin and Tolidine blue at pH 0.5 and 4.0 failed to reveal any appreciable abnormality in the first 2 weeks of loading

At the completion of the third week, examination of the periarticular cartilage showed derangement of the columnar pattern of cartilage cells. Fibrillation of the articular cartilage characterized by disruption of the matrix with cleft formation and deletion of ground substance, as revealed with Tolidine blue stain, was also noted (Figures 12 and 13)

Increased vascularity of the subchondral bone was accompanied by invasion



Figure 9 Photomicrograph of normal synovial membrane taken from a 3 week control knee joint (hematoxylin and eosin $\times 38$)



Figure 10 Photomicrograph of synovial membrane taken from a 3 week impacted knee joint (hematoxylin and eosin $\times 38$) Note increased collagen

Figure 11. Photomicrograph of pericapsular area in a 6-week impacted knee joint showing foreign body giant cells (hematoxylin and eosin $\times 32$).



Figure 12. Photomicrograph of degenerating periarthicular cartilage taken from a 3-week loaded tibia. "A" denotes capsule, "B" periarthicular cartilage, "C" subchondral bone (hematoxylin and eosin $\times 15$).

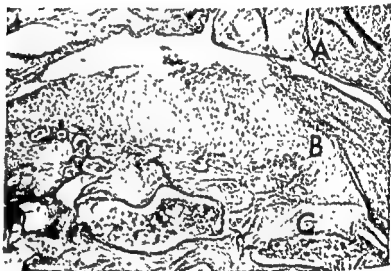


Figure 13. Higher magnification of Figure 12 showing marrow and blood vessels from the subchondral bone invading the zone of calcified cartilage (hematoxylin and eosin $\times 32$).

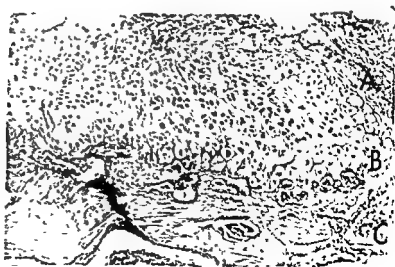




Figure 14 Photomicrograph of normal periarticular tibial cartilage from a 3 week control animal. A denotes capsule, B cartilage and C subchondral bone (hematoxylin and eosin $\times 15$)

of blood vessels into the cartilage (Figure 13). Periarticular cartilage from the control tibia is shown in Figure 14.

DISCUSSION

Previous studies

Radin and co-workers using a similar experimental model found that repetitive impact loading of rabbit knee joints resulted in subchondral bone stiffening (Radin et al 1973). They proposed that this stiffening is due to healing microfractures occurring consequent to repetitive impact loads. It has also been suggested that cartilage degeneration is preceded by and attributable to stiffening of the subchondral bone.

Their work, however, appears to suffer from two limitations. Firstly, the rabbit cartilage on which they based their conclusions was distal femoral while the subchondral bone used was proximal tibial. Statements relating subchondral bone stiffness to cartilage degeneration are therefore not necessarily valid (Radin et al 1973). Secondly, they have reported subchondral bone stiffening secondary to callus formation as early as the sixth day during impact loading. Mechanical studies of fracture healing in rabbits have shown that the original strength of

the fracture is not regained until the seventeenth day post fracture (Brighton & Krebs 1972).

Lercim et al (1974) studying patients with rheumatoid and osteoarthritis of the knee found that the hardness of the subchondral bone was significantly less in these subjects than in normal bone.

Subchondral bone changes

The findings in this study indicate that repetitive impact loading through rabbit knee joints results in a progressive increase in the deformability of the subchondral bone under a constant force. This is supported by the steady rise in the average deformation values of the impacted subchondral bone cores with time (Figure 6). The higher value of the modulus of elasticity in the control tibial core as opposed to the impacted core suggests that subchondral bone softening occurs with impact loading (Figure 5). The increased incidence of permanent deformation in the impacted cores (10) as opposed to the control (2) also suggests that the impacted bone was not as strong as the control.

Etiology of subchondral bone changes

No definite explanation for the changes noted in the subchondral bone is proposed from this work. Osteoporosis (decreased

morganic bone matrix) secondary to hyperemia of the subchondral bone could account for the increased fragility of the impacted tibial cores (Figure 13). This is supported by the work of Harrison et al (1953). They have shown, in osteoarthritic femoral heads, that vascular proliferation and marrow invasion result in osteoporosis. Seireg & Kemple (1969), however, found no change in the mineral or collagen content of rat tibiae subjected to prolonged cyclic loading.

The reaction of the synovial membrane in this experimental model is thought to be non-specific, although local or metabolic factors may have been induced. These could account for the changes seen.

The increasing deformation of the cancellous bone may have a more complex etiology. Since each loaded knee received 16,800 impacts per week, fatigue failure of individual trabeculae may be responsible. Fatigue fractures have been produced experimentally in cadaveric human femoral necks with cyclic loads approximating four times body weight (Griffiths et al 1971). While not conclusive, the abnormal trabecular seen in Figure 8 is suggestive of fatigue fractures. The lack of displacement coupled with the periosteal reaction resembles a fatigue fracture occurring in clinical practice. Absence of cellular activity may be explained by the preparation of the specimen, since the reflected light microscopy technique has the advantage of retaining the structural integrity of cancellous bone, but distorting the cellular detail. As a result, the cellular component of callus may be absent (Pugh et al 1972).

Isolated trabecular fatigue fractures of human femoral necks occurring in subchondral bone in association with osteoarthritis, rheumatoid arthritis, and subcapital fractures have been reported (Todd et al 1972).

It is unlikely that fatigue fractures can fully explain the etiology of the sub-

chondral bone changes. It should be stressed that their occurrence was rare and did not increase in frequency as the mechanical deformation increased.

Etiology of articular cartilage changes

The mechanism of cartilage degeneration with impulse loading is likewise unclear. Direct pressure is known to be incompatible with cartilage survival, presumably because of interference with nutrition (Salter & Field 1969). Repetitive loading may also interfere with cartilage survival by expressing a small amount of water from the matrix with each cycle. This results in a gradual diminution of the viscous component of dampening thus exposing the matrix to mechanical deformation and degeneration (Freeman 1973). Fatigue of cartilage produced experimentally is not associated with mucopolysaccharide depletion (Weightman et al 1973).

Harrison et al (1953) studying osteoarthritis in human femoral heads showed that there is early invasion of cartilage by marrow and subchondral blood vessels. They emphasize that this invasion first occurs in non-weightbearing areas. The periarticular non-weightbearing area from a 3-week impacted tibia supports this view (Figures 12 and 13). It must be emphasized that the hyperemia seen in the subchondral bone is non-specific and may be a local reaction to trauma.

Relationship of subchondral bone changes to cartilage degeneration

Increased deformability of the subchondral bone would result in decreased structural support of the overlying cartilage. Articular cartilage devoid of support would be subject to collapse under loading. This could produce high stress concentrations both internally and externally thus resulting in fatigue of cartilage.

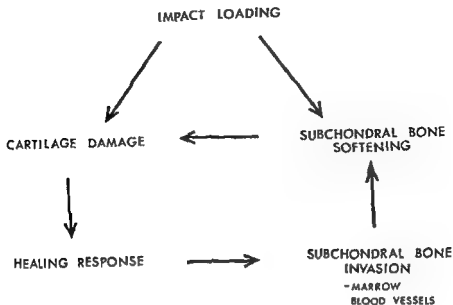


Figure 15 Diagram summarizing proposed mechanisms of experimental degenerative joint disease secondary to cyclic impact loading

The time relationship between cartilage and subchondral bone changes in experimental degenerative joint diseases is open to three theoretical pathways. Following induction by impulse loading cartilage degeneration may precede, follow or occur simultaneously with subchondral bone changes.

This work supports the concept that subchondral bone changes and cartilage degeneration occur concurrently in joints subjected to mechanical trauma by impact loading. Cartilage and subchondral changes were not seen until the third week of testing.

A summary of the proposed mechanism of experimental degenerative joint disease secondary to impact loading is shown in Figure 15.

SUMMARY

1) Eighteen male mature Whiteland rabbits received repetitive impulse loads slightly larger than body weight through one knee joint for periods of 1 to 6 weeks.

2) The subchondral bone cores from impacted tibiae showed progressive increased deformability under a constant force.

3) Reflected light microscopy showed evidence of fatigue fractures occurring in trabecula from the impacted tibiae.

4) The increased deformability of the impacted subchondral bone may be related to osteoporosis secondary to hyperemia.

5) Cartilage studies from impacted tibiae suggest that degeneration occurs concurrently with alterations in the mechanical properties of the subchondral bone.

6) Cartilage degeneration occurred first and with greater severity in non-weightbearing areas of the articular cartilage.

7) This mechanical model supports the view that cartilage degeneration may be affected by

- (1) the direct effect of repetitive mechanical compression, i.e. fatigue

inorganic bone matrix) secondary to hyperemia of the subchondral bone could account for the increased fragility of the impacted tibial cores (Figure 13). This is supported by the work of Harrison et al (1953). They have shown, in osteoarthritic femoral heads, that vascular proliferation and marrow invasion result in osteoporosis. Seireg & Kemple (1969), however, found no change in the mineral or collagen content of rat tibiae subjected to prolonged cyclic loading.

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THE EFFECT OF OSTEOTOMY AND CARTILAGE DAMAGE ON MITOTIC ACTIVITY

An Experimental Study in Rabbits

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Malmö Sweden

In 15 rabbits osteotomy and osteotomy including cartilage damage were performed. With autoradiography (^3H thymidine) it was shown that only one knee in the osteotomy group had labeled chondrocytes in the tibial cartilage. In the knees with articular damage labeled chondrocytes were found in the femur as well which could be the result of a factor liberated from the damaged cartilage, a factor stimulating mitotic activity.

Key words: cartilage, mitosis of chondrocytes, autoradiography, chalcones.

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Mitotic division of chondrocytes has never been demonstrated with any certainty in normal adult joint cartilage from animals or human beings. When a well defined zone with calcified cartilage has been formed basally in articular cartilage and when tidemark has developed the chondrocytes cease to divide (Minkin 1969, 1970; Hulth et al 1972; Telhag 1972). Previous investigations have shown that local traumatization of articular cartilage gives rise to local repair. The chondrocytes around the defect recover their ability to take up ^3H -thymidine i.e. to divide (De Palma et al 1966). Hvasdrup et al (1975) have shown that when the patella is scored chondrocytes in the femur and the tibia can also

take up tritiated thymidine. In the same investigation they found that after arthrotomy of the rabbit's knee without cartilage damage some chondrocytes were labeled with tritiated thymidine.

The aim of the present investigation was to determine the effect of osteotomy of the tibia and cartilage damage without arthrotomy and compare this with pure osteotomy of the tibia.

MATERIAL AND METHODS

Fifteen full grown rabbits were used (gray Silver). The animals were divided into three groups. All the animals were operated upon under intravenous Nembutal anesthesia (Aldobott) under sterile conditions. In group I a medial incision was made in the right knee over the medial tibial condyle and from there an osteotomy of the tibia was made about 2 cm from the proximal end of the tibia by sawing the condyle halfway to the lateral side (Figure 1). The left knee joint served as a control. In

- (ii) the decrease in mechanical support of the subchondral bone

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REFERENCES

- Brighton, C. T. & Krebs, A. G. (1972) Oxygen tension of healing fractures in the rabbit. *J Bone Jt Surg* 54-A, 323-332.
- Freeman, M. A. R. (1973) *Adult articular cartilage*. Ed Freeman, M. A. R. pp 33-245. Sir Isaac Pitman and Sons Ltd, London.
- Gardner, D. L. (1960) The experimental production of arthritis. *Ann Rheum Dis* 19, 297-305.
- Griffiths, W. E., Swanson, S. A. V. & Freeman, M. A. R. (1971) Experimental fatigue fracture of the human cadaveric femoral neck. *J Bone Jt Surg* 53-B, 136-143.
- Harrison, M. H. M., Schajowicz, F. & Trueta, J. (1953) Osteoarthritis of the hip. A study of the nature and evolution of the disease. *J Bone Jt Surg* 35-B, 598-626.
- Lereim, P., Goldie, I. & Dahlberg, E. (1974) Hardness of the subchondral bone of the tibial condyles in the normal state and in osteoarthritis and rheumatoid arthritis. *J orthop scand* 45, 614-627.
- Luft, J. H. (1961) Improvements in epoxy resin embedding methods. *J biophys biochem Cytol* 9, 409-414.
- Morrison, J. B. (1970) The mechanics of knee joint in relation to normal walk. *J Biomech* 3, 51-61.
- Pugh, J., Rose, R. & Radin, E. (1972) Technique for the study of the structure of bone. *Mic structures* 3, 23-27.
- Radin, E., Parker, H. G., Pugh, J., Steinberg, S., Paul, I. G. & Rose, R. (1973) Response of joints to impact loading—III. *J Biomech* 5, 51-57.
- Radin, E., Paul, I. G. & Lowy, M. (1970) A comparison of the dynamic force transmission properties of subchondral bone and articular cartilage. *J Bone Jt Surg* 52 A, 444-456.
- Salter, R. D. & Field, P. (1969) The effects of continuous compression on living articular cartilage. *J Bone Jt Surg* 51 A, 31-49.
- Seireg, A. & Kempke, W. (1969) Behavior of *in vivo* bone under cyclic loading. *J Biomech* 2, 455-461.
- Siegel, S. (1956) *Non parametric statistics in the behavioral sciences*. McGraw Hill Book Co Inc, Kogakusha Co Ltd, Tokyo.
- Simon, P. S., Radin, E., Paul, I. G. & Rose, R. (1972) Response of joints to impact loading. II. *In vivo* behavior of subchondral bone. *J Biomech* 5, 267-272.
- Todd, R. C., Freeman, M. A. R. & Pirie, C. (1972) Isolated trabecular fatigue fractures of the femoral head. *J Bone Jt Surg* 54, 723-728.
- Weightman, B. O., Freeman, M. A. R. & Swanson, S. A. V. (1973) Fatigue of articular cartilage. *Nature (Lond)* 244, 303-304.

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Financial support was obtained from Svenska Lakarsällskapet, Herman Järnhards Stiftelse and Miksa (1) under most Rheumatism.

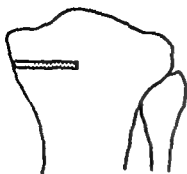


Figure 1 Osteotomy in the right knee



Figure 2 Osteotomy and cartilage damage in the left knee

group 2 the same procedure was carried out as in group 1 in the left knee but after making the osteotomy the articular cartilage was damaged for a length of 2 mm through the osteotomy line with a dentist's drill. Precautions were taken not to damage the femoral condyle (Figure 2). At no time was the synovial membrane cut. The right knee served as a control. In group 3 the right knee was operated upon as in group 1 and the left as in group 2.

Fourteen days after the operation the animals were killed by an iv overdose of Nembutal. Six hours before sacrifice $40 \mu\text{Ci}$ ^3H thymidine was injected into each knee joint. X rays were then taken to identify the osteotomy and to find out whether the epiphyseal line was closed. Both knee joints were removed and fixed in 10 per cent formalin. The tibia and the femur were dissected free and treated separately. With a circular saw the tibia and the femur were divided into two halves in the frontal plane. These halves were then decalcified in 40 per cent formic acid. The specimens were embedded in paraffin and cut into sections ($4-7 \mu$). The sections were stained with hematoxylin-eosin according to van Gieson and with toluidine blue. Autoradiograms of routine histological specimens from both knees were prepared according to the dipping method with Ilford K2 liquid emulsion. After exposure of the specimens for 3 weeks the autoradiograms were developed in Gevaert X ray developer G230 and fixed in Gevaert X ray fixer G305. The preparations

were stained through the emulsion with May hematoxylin.

RESULTS

Histological examination of specimens from two animals in group 3 revealed small signs of the epiphyseal line but both animals had a well defined layer of calcified cartilage and a 'tidemark' could be found.

In group 1, where osteotomy was performed in the right knee, two labeled chondrocytes were found in one knee, the tibia. However, no labeled chondrocytes could be found in the other right knee joints or in the left unoperated knee. The articular cartilage showed no signs of degeneration, such as death of the chondrocytes, flaking or fibrillation. Clusters were seen. At the margins proliferation of cells in and near the periosteum could be seen and in addition osteoblastic activity with new bone formation.

In group 2, where osteotomy was performed and the cartilage damaged in the operated left tibia, showed 1-3 labeled chondrocytes and two left femurs 1-4. The labeled chondrocytes in the tibia and femur were from the same knee. X labeling of the chondrocytes was found in the right unoperated knee joints. At the margins the same picture was seen as in group 1.

In group 3 three left tibias showed 1-4 labeled chondrocytes and one left femur showed two. In the same group one right tibia showed one labeled chondrocyte and one femur showed two. These labeled chondrocytes were from different knees.

Histologically a few clusters were found around the damaged cartilage. Around the defect there was fibrillation of the cartilage as well as necrosis of the chondrocytes close to the injury. The defect was filled with fibrous tissue. No labeled chondrocytes were found in the vicinity of the cartilage defect.

DISCUSSION

Previous investigators have shown that the ability of the chondrocytes to take up ^3H thymidine i.e. to divide decreases with advancing age and when a well defined zone with calcified cartilage can be found and when 'tidemark' has developed the chondrocytes cease to divide (Mankin 1968). Such tidemarks were found in all the joint cartilages in the present investigation, although residues of the epiphyseal line were found in the femoral head in rabbits.

There was a defect in the femoral head in rabbits. They could not find any degenerative cartilage changes outside the defect after 20 weeks. However, after 40-52 weeks degeneration of the cartilage was seen.

Reimann (1973) performed osteotomy in rabbits.

Reimann (1973) performed osteotomy in rabbits. They could not find any degenerative cartilage changes but no signs of osteophytes.

In this investigation the articular cartilage did not reveal any changes after 2 weeks except for local changes around the cartilage injury. This is in agreement with the findings of Wigren & Olerud (1973) who removed a part of the medial femoral condyle and fixed it back with a metal screw.

Havdrup et al. (1975) have shown that arthrotomy after scoring of the patella gave mitotic activity not only in the patella but also in the tibia and the femur in the same knee suggesting that a factor stimulating mitotic activity had been released. In the articular cartilage of the contralateral knee where only arthrotomy was performed some chondrocytes were labeled with ^3H thymidine.

In an earlier investigation, Telhag (1973) could not find any mitotic activity after arthrotomy alone. In this study we found sparse labeled chondrocytes also in the femur, which supports the theory that when the cartilage is damaged, a factor is liberated, which stimulates mitotic activity. This factor might be a proteolytic enzyme from the injured cartilage, a factor that has a chalone effect, i.e. an effect resulting in reducing the concentration of the cell specific inhibitors of the mitotic activity in normal adult joint cartilage.

REFERENCES

- De Palma A F., McKeever C. D. & Subin D. H. (1966) Process of repair of articular cartilage demonstrated by histology and autoradiography with tritiated thymidine. *Clin Orthop* 48: 229-240.
- Havdrup T., Hulth A. & Telhag H. (1975) Scattered mitoses in mature joint cartilage in rabbits after local trauma. *Clin Orthop* 113: 246-248.
- Hjertqvist S. & Lempert H. (1971) Histological, autoradiographic and microchemical studies of spontaneously healing osteochondral articular defects in adult rabbits. *Calcif Tiss Res* 8: 54-70.
- Hulth A., Lindberg L. & Telhag H. (1972) Mitosis in human osteoarthritic cartilage. *Clin Orthop* 81: 197-199.
- Mankin H. J. (1968) The effect of aging on articular cartilage. *N Y Acad Med Bull* 44: 545-552.
- Mankin H. J. (1970) The articular cartilage: a review. 440S Instructional Course Lectures. Vol. 11X: 204-221.
- Reimann I. (1973) Experimental osteoarthritis of the knee in rabbit induced by alteration of the load bearing. *Acta orthop scand* 41: 496-501.
- Telhag H. (1972) Mitosis of chondrocytes in experimental 'osteoarthritis' in rabbits. *Clin Orthop* 86: 224-229.
- Telhag H. (1973) DNA synthesis in degenerated and normal joint cartilage in fullgrown rabbits. *Acta orthop scand* 41: 604-610.
- Wigren A. & Olerud S. (1973) Reincorporation of an avascular articular surface bearing fragment. *Lpsat J med Sci., Suppl* 14.

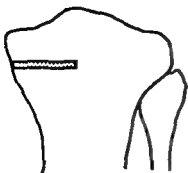


Figure 1 Osteotomy in the right knee

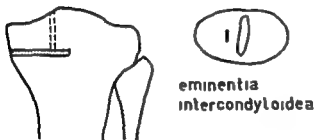


Figure 2 Osteotomy and cartilage damage in the left knee

group 2, the same procedure was carried out as in group 1 in the left knee, but after making the osteotomy the articular cartilage was damaged for a length of 2 mm through the osteotomy line with a dentist's drill. Precautions were taken not to damage the femoral condyle (Figure 2). At no time was the synovial membrane cut. The right knee served as a control. In group 3 the right knee was operated upon as in group 1 and the left as in group 2.

Fourteen days after the operation, the animals were killed by an iv overdose of Nembutal. Six hours before sacrifice $40 \mu\text{Ci } ^3\text{H}$ thymidine was injected into each knee joint. X rays were then taken to identify the osteotomy and to find out whether the epiphyseal line was closed. Both knee joints were removed and fixed in 10 per cent formalin. The tibia and the femur were dissected free and treated separately. With a circular saw the tibia and the femur were divided into two halves in the frontal plane. These halves were then decalcified in 40 per cent formic acid. The specimens were embedded in paraffin and cut into sections ($4-7 \mu$). The sections were stained with hematoxylin-eosin according to van Gieson and with toluidine blue. Autoradiograms of routine histological specimens from both knees were prepared according to the dipping method with Ilford K2 liquid emulsion. After exposure of the specimens for 3 weeks, the autoradiograms were developed in Gevaert X-ray developer G230 and fixed in Gevaert X-ray fixer G305. The preparations

were stained through the emulsion with Mayer's hematoxylin.

RESULTS

Histological examination of specimens from two animals in group 3 revealed small signs of the epiphyseal line but the animals had a well-defined layer of calcified cartilage and a 'lidemark' could be found.

In group 1, where osteotomy was performed in the right knee, two labeled chondrocytes were found in one knee in the tibia. However, no labeled chondrocytes could be found in the other right knee joints or in the left unoperated knee. The articular cartilage showed no signs of degeneration, such as death of the chondrocytes, flaking, or fibrillation. No clusters were seen. At the margins, proliferation of cells in and near the periosteum could be seen and in addition osteoblastic activity with new bone formation.

In group 2, where osteotomy was performed and the cartilage damaged, two operated left tibias showed 1-3 labeled chondrocytes and two left femurs 1-3. The labeled chondrocytes in the tibia and femur were from the same knee. No labeling of the chondrocytes was found in the right unoperated knee joints. At the margins, the same picture was seen as in group 1.

In group 3, three left tibias showed 1-4 labeled chondrocytes and one left femur showed two. In the same group one right tibia showed one labeled chondrocyte and one femur showed two. These labeled chondrocytes were from different knees.

Histologically, a few clusters were found around the damaged cartilage. Around the defect, there was fibrillation of the cartilage as well as necrosis of the chondrocytes close to the injury. The defect was filled with fibrous tissue. No labeled chondrocytes were found in the vicinity of the cartilage defect.

over a wide dose range (Langeland 1975b). The lowest doses being found effective were probably just above the physiologic. This makes it reasonable to study more thoroughly the *in vitro* effect of oestradiol in concentrations near to the physiologic.

MATERIAL AND METHODS

Young mature female rats of the Wistar/Kolff strain were used in experiments 1 and 3. In experiment 2 a Sprague Dawley strain of the same weight range was used. The animals were given the usual laboratory rat diet and water *ad libitum*. All rats were oophorectomized 1 week before being killed by a blow to the neck and decapitation. At oophorectomy the body weights ranged from 183 g to 210 g and at sacrifice from 206 g to 230 g. The experiments were designed for paired comparisons and accordingly all handling treatment incubations and analyses were run simultaneously for all samples to be compared as pairs. For one incubation series two animals were killed. The metaphyseal bones from the upper tibiae and the lower femurs of both sides were removed and handled as described previously (Langeland 1975a, b). All the bone pieces were pooled and thereafter divided into four portions of approximately equal weight.

Incubations and analyses were as described in detail elsewhere (Borje & Nichols 1960; Flanagan & Nichols 1969; Langeland 1975a, b). Also the incubation medium was as described previously (Langeland 1975b) except for the addition of different doses of oestradiol 17β (SIGMA) solubilized in alcohol and parathyroid hormone (Para Thor Mone Lilly) as follows:

Exp 1/Medium 1 (control)	5% C_2H_5OH
Exp 1/Medium 2	oestradiol $10^{-8} M$
Exp 1/Medium 3	oestradiol $10^{-6} M$
Exp 1/Medium 4	oestradiol $10^{-4} M$
Exp 2/Medium 1 (control)	5% C_2H_5OH
Exp 2/Medium 2	oestradiol $3 \times 10^{-8} M$
Exp 3/Medium 1 (control)	5% C_2H_5OH
Exp 3/Medium 2	parathyroid hormone (PTH) (Para Thor Mone Lilly) 1 USP unit per ml
	+ 5% C_2H_5OH

Exp 3/Medium 3

PTH 1 USP unit/ml +
oestradiol 17β $10^{-8} M$ + 5% C_2H_5OH

Exp 3/Medium 4

PTH 1 USP unit/ml +
oestradiol 17β 3×10^{-5} + 5% C_2H_5OH

Statistics: Wilcoxon's test for paired samples was applied to test for statistically significant differences (Wilcoxon 1945, 1947). The differences were considered significant when $2\alpha < 0.05$.

RESULTS

Most of the results from experiment 1 are summarized in Table 1 and Figure 1. The means and standard deviations are given. However, because these experiments were designed for paired comparison the standard deviations cannot be used for estimating significant differences. Among other things, weight and age of animals differed somewhat from one paired group to another. This may influence the standard deviations, but not the evaluation of the results when studied as paired samples.

Studying Table 1, it will be observed that the incorporation rates of the bone pieces treated with oestradiol 17β 10^{-8} , 10^{-6} or $10^{-4} M$ were not significantly different from controls.

In Table 2 are presented the synthesis and incorporation patterns of the bone pieces incubated with oestradiol- 17β $3 \times 10^{-5} M$. The synthesis rate was significantly reduced with this high oestradiol concentration in the medium while the percentage of synthesized collagen incorporated into the bone was unchanged, as was the percentage of total collagen in incubated bone that was passively solubilized in the incubation medium.

As can be seen from Table 1 and Figure 2 there was a greater variance in the results when studying the resorption than when looking at the incorporation.

THE *IN VITRO* EFFECT OF OESTRADIOL ON COLLAGEN METABOLISM IN METAPHYSEAL RAT BONE

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Surviving bone pieces from the femoral and tibial metaphyses of young castrated female rats have been incubated for 6 hours with concentrations of oestradiol-17 β ranging from 10^{-9} M to 3×10^{-6} M and the *in vitro* collagen metabolism studied. The addition of oestradiol did not produce any change in the resorption patterns of bone collagen expressed as release of hydroxyproline to the medium. Parathyroid hormone in the incubation medium increased the resorption and decreased the incorporation rate insignificantly. Addition of both parathyroid hormone and oestradiol to the incubation medium produced a significant increase in resorption and a decrease in incorporation rate as compared with the control incubations. The bone pieces incubated with oestradiol 17 β 3×10^{-6} synthesized and incorporated significantly less hydroxyproline than the control bone pieces. This is, however, a very high concentration of the hormone and the physiological significance of the observation is doubtful.

Key words: bone resorption, bone regeneration, collagen, oestradiol, parathyroid hormone

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The *in vitro* effects of oestrogens upon bone have been studied in a few works during the last decade (Stern 1969, Atkins et al 1972, Nordin et al 1970). All these studies have been based on some kind of tissue culture technique. They have been mostly concerned with the resorption of bone minerals, and very high concentrations of oestrogens have as a rule produced a reduced resorption rate or an inhibition of the parathyroid induced bone resorption.

The tissue culture techniques are, however, limited to studies of foetal or neonatal bone. Great progress would

therefore be made if any similar effects were demonstrable in mature bone *in vitro*.

In target tissues oestrogens have been found to induce the synthesis of a specific protein *in vitro* (Katzenelehnbozen & Gorski 1972, Means & O'Malley 1971, 1972). In contrast to the reduced resorption rate of the tissue culture of bone, this specific protein was synthesized at what is believed to be physiologic doses of oestrogens (Exley 1969, Brown Grant et al 1970). Administered *in vivo* oestradiol has been shown to be effective in reducing bone collagen resorption *in vitro*.

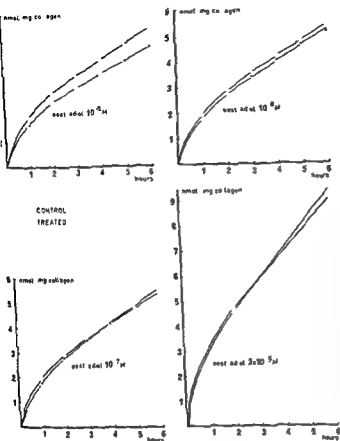


Figure 1 Total cumulative release of hydroxyproline to the medium during the 6 hours of incubation with different doses of oestradiol in the medium. Each point represents the mean of 3 to 7 samples. The standard deviations have been omitted since they overlapped each other. In each part of the figure the mean of one treated series and the corresponding untreated control series (experiments 1 and 2) are given. None of the differences between treated and corresponding control incubations were significant.

two strains of rats used in the present study should be noted.

DISCUSSION

Stimulating effects on protein synthesis of oestrogens added *in vitro* have been reported only in studies of target tissues (Katzenellenbogen & Gorski 1972, Means & O'Malley 1971, 1972). Studies on bone from mammals other than mice (Vaes & Nichols 1962, Atkins et al 1972, Stern 1969, Nordin et al 1970) have never revealed any stimulating effect of oestrogens on bone collagen synthesis *in vitro*. However, as pointed out in the introduction most of these studies have been undertaken with hormone concentrations far from what is believed to be "physi-

ologic". According to Exley (1969) the physiologic non-oestrus level of oestradiol-17- β in peripheral rat plasma is 1-2 ng per 100 ml plasma ($\approx 1-2 \times 10^{-10}$ M). It is not obvious that a similar concentration added *in vitro* is comparable. However, the doses most effective in stimulating protein synthesis in uterine tissue in the work of Katzenellenbogen & Gorski (1972) were 10^{-6} to 10^{-8} M, in other words concentrations near to the physiologic.

Based on these facts the present study was first planned with concentrations of 10^{-6} to 10^{-7} M of oestradiol-17- β . Although a slightly higher mean incorporation rate of the oestradiol 10^{-6} M group (Figure 1) can be seen, the treated bone did not behave significantly differently from control bone in any of the examined param-

Table 1 Collagen metabolism in rat metaphyseal bone treated in vitro with different doses of oestradiol-17- β (experiment 1) Incorporation and resorption are given in nanomols per mg incubated collagen per hour incubation In this table the net resorption and incorporation are given (cf text and Figure 1) "Solubility per cent" is the percentage of the collagen in incubated bone passively solubilized in the medium S D = Standard deviation

Treatment	n	Incorporation Mean \pm S D	Resorption Mean \pm S D	Solubility Mean \pm S D
Control	7	0.49 \pm 0.05	0.41 \pm 0.17	0.152 \pm 0.056
Oestradiol 10^{-9} M	7	0.57 \pm 0.05	0.29 \pm 0.11	0.150 \pm 0.061
Oestradiol 10^{-8} M	7	0.46 \pm 0.05	0.40 \pm 0.19	0.152 \pm 0.060
Oestradiol 10^{-7} M	7	0.54 \pm 0.14	0.39 \pm 0.25	0.159 \pm 0.078

1 a-d, that there was no significant difference in the total release of hydroxyproline to the medium during the total incubation period, and accordingly no difference in the amount of collagen passively solubilized in the medium (Tables 1 and 2 - "Solubility") The total hydroxyproline found in the medium derives from three different sources 1 Active cell mediated collagen resorption 2 Passive collagen/hydroxyproline solubilization in the medium 3 Newly synthesized hydroxyproline not incorporated into the bone pieces (Flanagan & Nichols 1969)

The results of the present study concerning the possible "interaction" between oestradiol and PTH are summarized in Table 3 and Figure 3 As will be seen, there was an insignificant difference between control and parathyroid hormone treated bone in collagen synthesis rates Adding oestradiol-17- β to the medium in addition to PTH reduced

incorporation rates to values significantly below the results of the controls However, none of the oestradiol PTH treated groups present synthesis or incorporation rates significantly different from those treated with PTH alone

There was no difference in the percentage of synthesized hydroxyproline incorporated into the bone pieces (Table 3)

The addition of PTH to the incubation medium (Figure 3) increased the resorption rate insignificantly ($0.05 < 2\alpha < 0.10$) When oestradiol-17- β 10^{-9} M or 3×10^{-8} M was added as well, the resorption rates significantly increased compared with untreated control incubations, while there was no significant difference compared with the bone pieces treated with parathyroid hormone alone (Figure 3)

The percentage of collagen passively solubilized in the medium during the first 2-3 hours of incubation remained unaffected by the treatment given

The different metabolic pattern of the

Table 2 Collagen metabolism in rat metaphyseal bone treated in vitro with oestradiol 17- β 3×10^{-11} M Values of synthesis are given in nanomol hydroxyproline per hour per mg incubated collagen

Treatment	n	Synthesis Mean \pm S D	Per cent incorporated Mean \pm S D	Solubility percentage Mean \pm S D
Control	6	1.26 \pm 0.10	78.4 \pm 5.5	0.224 \pm 0.048
Oestradiol 3×10^{-11} M	6	1.09* \pm 0.16	78.5 \pm 8.1	0.250 \pm 0.075

* Significantly different from control ($P < 0.05$)

This difference may possibly be caused by the longer incubation time possible with tissue culture techniques and by the addition of serum to the incubation medium in the cited studies (Stern & Raisz 1966, 1967). Moreover, based on the theory that oestrogens inhibit the bone resorptive activity of parathyroid hormone (Burkhardt & Jowsey 1967, Jowsey & Raisz 1968, Nordin et al 1970), the studies of Stern (1969), Atkins et al (1970) have been concerned with the effect of oestrogens on parathyroid induced bone resorptions. This oestrogen/parathyroid hormone counteraction theory has been considered in experiment 3 of the present study. However, oestradiol 17β in the tested concentrations had virtually no antiresorptive effect upon the bone treated with PTH. Since the techniques applied in the present study are very different from the cited tissue culture studies (Stern 1969, Atkins 1972) they are not directly comparable.

However the concentrations found effective in reducing bone resorption *in vitro* are very high—10 000 to 100 000 times higher than what is believed to be physiologic. This does not correspond well to the results obtained with the hormone administered *in vitro* as reported previously (Langeland 1975b), where doses probably near to the physiologic were found effective in inhibiting resorption of bone collagen.

As pointed out by Stern (1969) several steroids inhibit bone resorption (and bone synthesis?) when added *in vitro* at these high concentrations. She doubts that the effects of steroids at these concentrations are related to their hormonal activity. At least it seems questionable whether the effects found at these high concentrations are comparable with the effects found after *in vivo* administration of the hormone.

In conclusion it may be pointed out that in the present study oestradiol added *in vitro* in physiologic amounts had no

effect on bone metabolism, and it had no antiresorptive effect on PTH treated bone. In a previous study (Langeland & Teig 1975) it was found that oestradiol administered *in vivo* had the same antiresorptive effect on bone in thyroparathyroidectomized rats as it had in animals with intact thyroparathyroid glands. All these findings suggest that the effect of oestradiol on bone is independent of PTH. However, since these effects are not demonstrable when the hormone is administered *in vitro* the possibility that it may act indirectly, e.g., via the hypophysis or some other mediator, should be investigated further.

REFERENCES

- Atkins D., Zanelli J. M., Peacock M. & Nordin B. E. C. (1972) The effect of oestrogens on the response of bone to parathyroid hormone *in vitro*. *J. Endocr.* **34**, 107–117.
- Borle A. B. & Nichols G. (1960) Metabolic studies of bone *in vitro*. 1. Normal bone. *J. Biol. Chem.* **235**, 1206–1210.
- Brown Grant K., Exley D. & Nafstolin F. (1970) Peripheral plasma oestradiol and luteinizing hormone concentrations during the oestrous cycle of rat. *J. Endocr.* **48**, 293–296.
- Burkhardt J. M. & Jowsey J. (1967) Parathyroid and thyroid hormones in the development of immobilization osteoporosis. *Endocrinology* **81**, 1033–1062.
- Exley D. (1969) The ultramicrodetermination of oestrogens in rat peripheral plasma. *Acta endocr. (Kbh.) Suppl.* **138**, 18.
- Flanagan B. & Nichols G. (1969) Bone matrix turnover and balance *in vitro*. 1. The effects of parathyroid hormone and thyrocalcitonin. *J. clin. Invest.* **48**, 593–606.
- Jowsey J. & Raisz L. G. (1968) Experimental osteoporosis and parathyroid activity. *Endocrinology* **80**, 334–396.
- Katzellenbogen B. S. & Gorski J. (1972) Estrogen action *in vitro*. Induction of the synthesis of a specific uterine protein. *J. Biol. Chem.* **247**, 1999–1303.
- Kuchler R. J. & Grauer R. C. (1967) Effects of natural estrogens on L-Strain Fibroblasts in tissue culture. *Proc. Soc. exp. Biol. Med.* **110**, 251–259.
- Langeland A. (1975a) Effects of oestradiol on bone collagen metabolism. An experimental study in female rats. Thesis, Oslo.

Table 3 Collagen metabolism in rat metaphyseal bone treated *in vitro* with parathyroid hormone and oestradiol 17- β . The total collagen synthesis, percentage of synthesized collagen incorporated into incubated bone pieces and percentage of incubated bone collagen passively solubilized in the medium are given. Values in nmol per mg collagen per hour of incubation or in percentages

Treatment	n	Synthesis Mean \pm S D	Per cent incorporated Mean \pm S D	Solubility percentage Mean \pm S D
Control	6	1.05 \pm 0.17	70.4 \pm 3.8	0.20 \pm 0.08
Parath hormone	7	0.99 \pm 0.14	71.6 \pm 4.2	0.22 \pm 0.04
Parath + oestradiol 10^{-5}	6	0.93* \pm 0.13	71.1 \pm 4.3	0.31 \pm 0.09
Parath + oestradiol 3×10^{-5}	7	0.89* \pm 0.18	69.0 \pm 2.4	0.25 \pm 0.08

* Significantly different from control ($P = 0.02$)

elers. Raising the oestradiol concentration to 3×10^{-5} M reduced the collagen synthesis rate significantly, and produced an insignificant reduction in the resorption rate. This is a concentration of oestradiol-17- β comparable with the concentrations Kuchler & Grauer (1962) found to inhibit growth of L-strain fibro-

blasts. Atkins et al (1972) found oestradiol to inhibit the resorptive action of parathyroid hormone at a concentration near to 10^{-4} M, and at 10^{-5} M Stern (1969) found a similar effect. These experiments were performed in tissue culture.

The results obtained in the present study do not reveal any effect of oestradiol-17- β , added *in vitro*, upon bone resorption. The works of Stern (1969) and Atkins et al (1972) revealed a clear-cut reduction in PTH-induced bone resorption at high concentrations of oestradiol.

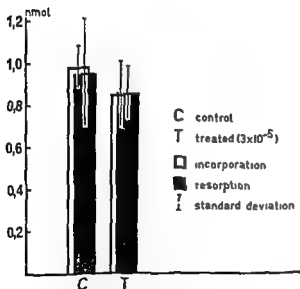


Figure 2 In vitro treatment of metaphyseal bone from castrated female Sprague Dawley rats. The mean incorporation and resorption rates of bone pieces treated with oestradiol-17- β 3×10^{-5} M and their paired untreated controls are given. Each column represents the mean and standard deviation of 6 incubations. The treated group (T) synthesized significantly less hydroxyproline than the control incubations ($2\alpha = 0.05$)

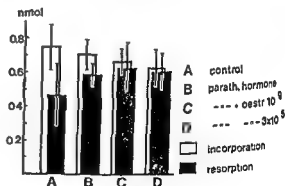


Figure 3 In vitro metabolism of metaphyseal rat bone treated with parathyroid hormone alone and in combination with oestradiol 17- β 10^{-5} M or 3×10^{-5} M. Values are in nanomol per mg incubated bone collagen per hour of incubation. The incorporation rates of group C and D are significantly reduced compared with group A and the resorption rates of the same groups are significantly increased as compared to group A ($2\alpha = 0.05$)

THE SPINAL ABNORMALITIES IN THALIDOMIDE EMBRYOPATHY

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In 1968 a study was made of the spinal changes in 32 children with multiple congenital abnormalities due to thalidomide. Twenty-eight of these children have been traced and their spinal changes reviewed. Only four patients had normal spines on radiography. In eight children scoliosis was present and had progressed though it was still of mild degree. Disc and end plate abnormalities were seen in 14 children and in some appeared to be progressive leading to intervertebral fusion.

Key words: thalidomide, congenital defects, scoliosis, spinal deformity.

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The limb defects of children affected by thalidomide and the problems associated with their management have been the subject of considerable attention in the orthopaedic and prosthetic literature. However almost any system of the body may be involved in the syndrome of thalidomide embryopathy (Smithells 1973). Marguardt first drew attention to humps in the vertebral column in this syndrome in 1967. A radiological study of the spines of 64 children with thalidomide induced deformities was made by Andrian Werburg (1966). Thirty nine had scoliosis and 16 had a dorsolumbar kyphosis. Similar changes have been reported in the German literature by Peter sen (1967), Jäfer et al (1967) and Ruf link (1974).

The spinal abnormalities of 32 children who were then between 4 and 8 years of age were reported by Nichols et al in 1968. These children are now between 10 and 14 years of age at the

start of their adolescent growth spurt which is an appropriate time to review the extent of their spinal deformities.

MATERIAL

Limb defects

All 32 children have upper limb defects, one child has one normal arm. Nineteen children have normal lower limbs, three have normal lower limb bones with one or both hip joints dislocated and one has proximal focal femoral deficiency but otherwise normal legs.

Previous spinal changes

The spinal abnormalities were previously classified as follows:

	Children
1 Local anomalies of bone development	
a) Spina bifida	3
b) Fusion of adjacent spinous processes	2
2 Scoliosis	18
3 Wedge deformity of solitary vertebral bodies	4
4 Calcification in intervertebral spaces seen in the form of horizontal flakes	3

- Langeland, N (1975b) In vitro studies on collagen metabolism in metaphyseal rat bone A The effect of pre-treatment with oestradiol 17- β *Acta endocr (Abh)* 80, 775-783
- Langeland, N & Teig, V (1975) In vitro studies on collagen metabolism in metaphyseal rat bone C The effect of oestradiol-17- β in hypophysectomized and in thyro parathyroidectomized animals *Acta endocr (Abh)* 80, 795-800
- Means, A R & O'Malley, B W. (1971) Assessment of sex steroid action in vitro *Acta endocr (Abh)* 153, 318-336
- Means, A R & O'Malley, B W (1972) Mechanism of estrogen action early transcriptional and translational events *Metabolism* 21, 357-370
- Nordin, B E C, Young, M M, Bulusu, L & Horsman, A (1970) Osteoporosis reexamined In *Osteoporosis* Ed Barzel, U S, pp 47-67 Grunc & Stratton, New York/London
- Stern, P H (1969) Inhibition by steroids of parathyroid hormone induced Ca^{45} release from embryonic rat bone in vitro *J Pharm exp Ther.* 168, 211-217
- Stern, P H & Raisz, L G (1966) The effects of serum proteins on the parathyroid hormone induced release of Ca^{45} from embryonic bone in vitro *Fed Proc* 25, 243
- Stern, P H & Raisz, L G (1967) An analysis of the role of serum in parathyroid hormone induced bone resorption in tissue culture. *Exp Cell Res* 46 106-120
- Vaes, M M & Nichols, G (1962) Metabolism of glycine 1- C^{14} by bone in vitro Effects of hormones and other factors *Endocrinology* 70, 890-901
- Wilcoxon, F (1945) Individual comparisons by ranking methods *Biometrics* 1 80-83
- Wilcoxon, F. (1947) Probability tables for individual comparisons by ranking methods *Biometrics* 3, 119-122

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Figure 1. Same subject aged 11 years 11 months. Lateral vertebral fusion from T11 to T12 and L1 to L2.

with associated symptoms and functional restriction might occur relatively early in life and the need for continuing observation and for wider study of similar children was emphasized.

In the current review two main types of spinal abnormality were noted: scoliosis and disc changes. The presence of even a mild scoliosis at the start of the adolescent growth spurt is a cause for concern. The degree of scoliosis present though minor in most cases was nevertheless measurable and in eight children became significantly worse. The curves

were all long and paralytic in type. In this small series there did not appear to be a correlation between the presence of scoliosis and limb asymmetry. Four children with thoracic curves had asymmetrical upper limbs whereas ten children with thoraco-lumbar curves and two with lumbar curves all had symmetrical indeed normal lower limbs.

Changes in the discs and end plates were found in 12 of the 32 children in the initial study; they were present in fourteen of the 28 children in the current review and in eight of these intervertebral fusion had occurred. The only other spinal condition in which fusion such as this takes place is ankylosing spondylitis but there was no evidence that these children were suffering from this disease. It was thought at first that decreasing lumbar lordosis might result from the presence of fusion of the anterior parts of the vertebral bodies with cessation of growth at this site and continuing growth of the posterior elements. In only three of the 14 children in whom repeated measurements have been made has the lumbar curvature decreased and it does not appear to be related to the type of limb deformity which is present or to foot usage. The point we wish to emphasize is that in some children disc and end plate abnormalities which may lead to vertebral fusion do seem to be extending to other levels in the spine. The implications of this in these children who depend so much on supple spinal movements to use their deficient limbs to best advantage are obvious. Further studies are in progress and careful follow up is essential.

ACKNOWLEDGEMENTS

We are indebted to our orthopaedic colleagues at the Nuffield Orthopaedic Centre and elsewhere for permission to study the children in their care and for arranging for radiographs to be taken.

- End-plate and disc deformities
 - (a) Disc space narrowing alone 2
 - (b) Deformities of discs and end-plates resulting in abnormal vertebral body shape, one vertebra overgrowing to compensate for a defect in an adjacent vertebra, usually of the anterior surfaces 9
 - (c) Disc narrowing and deformity leading to partial or complete fusion of adjacent vertebral bodies 5

Present review

Recent radiographs of the spines of 28 of the children were obtained. The changes between the original study and the current review were as follows:

Local anomalies of bone development Defects of the neural arch were more obvious in the follow-up series. In seven children minor changes such as asymmetry between the size of ribs, transverse processes or pedicles, were apparent on the follow-up films but not on the earlier ones.

Scoliosis In all, 20 children had scoliosis of varying degrees. In eight children the scoliosis had become worse. In two, the scoliosis was of mild degree originally, and later reversed. In two, no scoliosis was apparent on review. Two children developed scoliosis which was not noted originally. In most of the children the scoliosis measured less than 15° and was of the long paralytic type. In one child the curve measured 25°. One child in the earlier series had a severe scoliosis but in addition to being exposed to thalidomide he had multiple epiphyseal dysplasia and he died before review.

Wedge deformity In four cases additional deformities of the vertebrae were noted.

Disc space calcification In two additional children disc space calcification had appeared. In one this was seen at only two levels but in the other it was extensive.

Disc and end plate abnormalities In the earlier study this type of change was present in 12 patients; it had appeared in two or more in the current review. In two children frank intervertebral fusion which had not been noted before had occurred. In two others intervertebral fusion had extended to other levels in the spine, as seen in Figures 1 and 2. Reduction of the lumbar lordosis was noted in 10 children. Only two of the latter had normal legs.

DISCUSSION

In the earlier study of this group of 32 children with multiple congenital limb



Figure 1 Lumbar spine of child aged 4 years 2 months, showing deformities of the discs and end plates from T9 to S1 and partial anterior fusion of L3 and L4 vertebral bodies.

deformities, believed to be due to thalidomide, only eight (25 per cent) had no radiological abnormality of the spine. Mild scoliosis was noted in 17 patients. Twelve patients had abnormalities of the end-plates and intervertebral discs ranging from narrowing of the disc space to severe deformities of the end plates and anterior fusion of the vertebral bodies. It was first thought that the changes might be secondary to frequent hyperflexion associated with using the feet for dressing, feeding and playing, but abnormalities were found in children with severely deformed lower limbs who were unable to use their feet in this way. Though there was no evidence of progression of abnormalities in the spine, it was thought that secondary degenerative changes



Figure 2 Same subject age 11 years 11 months
Intervertebral fusion T11 to T12 and L1 to L2

with associated symptoms and functional restriction might occur relatively early in life and the need for continuing observation and for wider study of similar children was emphasized.

In the current review two main types of spinal abnormality were noted: scoliosis and disc changes. The presence of even a mild scoliosis at the start of the adolescent growth spurt is a cause for concern. The degree of scoliosis present though minor in most cases was nevertheless measurable and in eight children became significantly worse. The curves

were all long and paralytic in type. In this small series there did not appear to be a correlation between the presence of scoliosis and limb asymmetry. Four children with thoracic curves had asymmetrical upper limbs whereas ten children with thoraco-lumbar curves and two with lumbar curves all had symmetrical indeed normal, lower limbs.

Changes in the discs and end plates were found in 12 of the 32 children in the initial study; they were present in fourteen of the 28 children in the current review and in eight of these intervertebral fusion had occurred. The only other spinal condition in which fusion such as this takes place is ankylosing spondylitis but there was no evidence that these children were suffering from this disease. It was thought at first that decreasing lumbar lordosis might result from the presence of fusion of the anterior parts of the vertebral bodies with cessation of growth at this site and continuing growth of the posterior elements. In only three of the 14 children in whom repeated measurements have been made, has the lumbar curvature decreased and it does not appear to be related to the type of limb deformity which is present, or to foot usage. The point we wish to emphasize is that in some children disc and end plate abnormalities which may lead to vertebral fusion do seem to be extending to other levels in the spine. The implications of this in these children who depend so much on supple spinal movements to use their deficient limbs to best advantage are obvious. Further studies are in progress and careful follow up is essential.

ACKNOWLEDGEMENTS

We are indebted to our orthopaedic colleagues at the Nuffield Orthopaedic Centre and elsewhere for permission to study the children in their care and for arranging for radiographs to be taken.

- 5 End plate and disc deformities
- (a) Disc space narrowing alone 2
 - (b) Deformities of discs and end-plates resulting in abnormal vertebral body shape, one vertebra overgrowing to compensate for a defect in an adjacent vertebra, usually of the anterior surfaces 11
 - (c) Disc narrowing and deformity leading to partial or complete fusion of adjacent vertebral bodies 5

Present review

Recent radiographs of the spines of 28 of the children were obtained. The changes between the original study and the current review were as follows

Local anomalies of bone development Defects of the neural arch were more obvious in the follow-up series. In seven children minor changes, such as asymmetry between the size of ribs, transverse processes or pedicles, were apparent on the follow up films but not on the earlier ones.

Scoliosis In all, 20 children had scoliosis of varying degrees. In eight children the scoliosis had become worse. In two, the scoliosis was of mild degree originally, and later reversed. In two, no scoliosis was apparent on review. Two children developed scoliosis which was not noted originally. In most of the children the scoliosis measured less than 15° and was of the long paralytic type. In one child the curve measured 25°. One child in the earlier series had a severe scoliosis, but in addition to being exposed to thalidomide he had multiple epiphyseal dysplasia and he died before review.

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THE CHANGED PATTERN OF BONE AND JOINT TUBERCULOSIS IN NORWAY

BERNHARD PAUS

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The reduced incidence of bone and joint tuberculosis in Western countries and the change in the age groups afflicted are well known facts. In addition, there are other less conspicuous changes: multiple lesions and involvement of the spine and sacro iliac joints are rarer than before while trochanteric involvement is becoming more frequent. In spinal cases the lesion is now more often localized to the dorsal region. All these changes may be due to the change in age distribution of the patients.

Key words: spinal tuberculosis, changed pattern, bone and joint tuberculosis, clinical picture, pattern.

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It is a well known fact that tuberculosis of bone and joint has practically disappeared in many Western countries, e.g., Norway. It therefore seems appropriate to report on the present day status of the disease as well as to make a comparison with the situation some decades ago.

The incidence of new cases of tuberculosis of all types in Norway has declined during the period 1946 to 1975 by 90 per cent from 309.4 per 100 000 population to 11.9. By law, all new cases of tuberculosis in the country should be notified to the health authorities. For various reasons the notification during the war was not reliable and therefore only post war numbers are used.

The incidence of bone and joint tuberculosis has also declined. Five-year numbers are used in order to get numbers of a reasonable size. In the period 1946-50, a total of 264 new cases were notified

per 100,000 population, in 1971-75 the number was 2.6, i.e., a drop of 90 per cent. The decline has been greatest in the younger age groups, with an average of 96 per cent for those below 50 years and 63 per cent for older people (Table 1).

The clinical picture in patients with bone and joint tuberculosis has changed. To study this change, records of two groups of patients were reviewed. One group consisted of the first 100 patients admitted to Martina Hansens Hospital, following its inauguration in 1936, and the second group consisted of the last 100 patients admitted up to the end of 1975. It needed less than 1 year to collect the first group, and approx. 11 years (1970-75) to collect the second. This gives an indication of the reduced incidence of the disease. Moreover, in 1936, the hospital was only one of seven hospitals for bone and joint tuberculous patients, while to-

REFERENCES

- Andrian-Werburg, H von (1966) Wirbelsäulenbefunde bei schweren Extremitäten Missbildungen *Beitr Orthop Traum* **13**, 776-778
- Jager, M, Refior, H J & Zenker, H (1967) Vergleichende Untersuchungen zur Frage der Fortentwicklungsstörung der Wirbelsäule bei Kindern mit Dysmelie Syndrom und Kindern mit Peromelien *Z Orthop* **103**, 283-293
- Marquardt, E (1967) *Monographie über die Rehabilitation der Dysmelie-Kinder (Dysmelie-Arbeitslagung, Heidelberg 1965)* Bartmann, Frechen/Köln
- Nichols, P J R, Boldero, J L, Goodfellow, J W & Hamilton, A (1968) Abnormalities of the vertebral column associated with thalidomide-induced limb deformities *Orthop (Oxford)* **1**, 71-90
- Petersen, D (1967) Über Wirbelsäulenmissbildungen bei Dysmelie-Kindern *Z Orthop* **103**, 386-394
- Ruffing, L (1974) Fehlbildungen der Wirbelsäule im Bereich der Bandscheibenräume bei der Thalidomidembryopathie Abstracts World Congress of International Society for Prosthetics and Orthotics, Montreux 1974 p 125
- Smithell, R W (1973) Defects and disabilities of thalidomide children *Brit med J* **1**, 269-272

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The reduced incidence of bone and joint tuberculosis in Western countries and the change in the age groups afflicted are well known facts. In addition there are other less conspicuous changes: multiple lesions and involvement of the spine and sacro iliac joints are rarer than before while trochanteric involvement is becoming more frequent. In spinal cases the lesion is now more often localized to the dorsal region. All these changes may be due to the change in age distribution of the patients.

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The clinical picture in patients with bone and joint tuberculosis has changed. To study this change, records of two groups of patients were reviewed. One group consisted of the first 100 patients admitted to Martina Hansens Hospital following its inauguration in 1936 and the second group consisted of the last 100 patients admitted up to the end of 1975. It needed less than 1 year to collect the first group, and approx. 6 years (1970-75) to collect the second. This gives an indication of the reduced incidence of the disease. Moreover, in 1936 the hospital was only one of seven hospitals for bone and joint tuberculous patients, while to-

day all patients with this ailment are supposed to be referred to this hospital

Table 1 Notified cases of bone and joint tuberculosis per 100 000 population in Norway (cf 1946-50 and 1971-75)

Age	Notified cases/100,000		Reduction in per cent
	1946-50	1971-75	
0-14 years	14.2	0.4	96
15-29 years	43.8	0.3	
30-49 years	21.2	2.5	
50-59 years	19.3	5.2	63
60+ years	12.7	6.7	

The age distribution of the patients has changed. In the 1936 group, 35 patients were below 20 years of age and in 1970-75 there were two. In the 1936 group, one patient was more than 50 years old, in the 1970-75 group there were a total of 80 (Table 2).

Table 2 Age of patients with bone and joint tuberculosis admitted to Martina Hansens Hospital (cf 1936 and 1970-75)

Age (years)	1936	1970-75
0-9	19	2
10-19	16	-
0-19	35	2
20-34	49	4
35-49	15	14
50-64	1	49
65	-	31
	100	100

There have also been other, less conspicuous changes in patients with bone and joint tuberculosis. Localization of the lesion to the spine or sacro-iliac joints, as well as multiplicity of bone and joint lesions, has become less frequent. These reductions are statistically significant. A registered increase in hip joint involvement is, however, not significant (Table 3).

A review was also made of the records of the first 100 patients treated at the hospital for tuberculosis of the spine and discharged in 1936-38 and the last 100 discharged at the end of 1975. It was necessary to go back 12 years to 1963 to collect this number of patients. In this latter group, 32 patients were treated for a recurrence of tuberculosis in the same vertebrae 6 to 36 years after onset.

Table 3 Localization of lesions in patients with bone and joint tuberculosis admitted to Martina Hansens Hospital (cf 1936 and 1970-75)

	1936	1970-75
Spinal lesions*	55	24
Sacro-iliac joint lesions	14	-
Trochanteric lesions	1	18
Hip joint lesions	15	23
Other lesions	29	36
Total lesions	113	101
Multiplicity	17 patients	1 patient

* Patients with multiple lesions in the spine are listed once only.

Multiplicity of spinal lesions has declined from 109 lesions in the first group to 101 in the more recent group. The number of affected vertebrae is the same: 303 and 299. Involvement of the dorsal region was more frequent in the recent group, the increase being probably statistically significant. This was observed to an equal extent in recurring and new cases (Table 4).

Table 4 Localization of spinal involvement in patients admitted to Martina Hansens Hospital for tuberculosis of the spine (cf 1936-38 and 1963-75)

	1936-38	1963-75
Cervical region	4	2
Dorsal region	42	59
Lumbar region	63	40

Cases with dorsolumbar lesions are listed as dorsal if the lumbar lesion was not dominant.

Table 5 Totalisation of lesions in patients with bone and joint tuberculosis in different age groups

Age	No of patients	Localization to the		Multiplicity of lesions
		Spine	S I joint*	
0-34 years	50	57 (63%)	12	14
35-49 years	59	18 (31%)	2	4
50-64 years	50	13 (26%)	—	—
65+ years	31	4 (13%)	—	—

All sacro iliac lesions were bacteriologically and/or histologically verified as tuberculous and do not represent misdiagnosed cases of ankylosing spondylitis Bechterew

DISCUSSION

The reduced incidence of bone and joint tuberculosis from 1946 to 1975 corresponds with the reduced incidence of tuberculosis in general over this period. The reasons for this reduction will not be discussed here.

The change in age distribution of patients with bone and joint tuberculosis from 1936 to 1970 is explained by the different reductions in incidence of notified new cases in the population in the various age groups. Theoretically also a change in the population should be considered but this possibility must be discarded as this change is minimal. The age group 0-19 years in the population declined from 34.6 to 31.7 per cent but the number of patients has changed from 75 to two. The age group 50 years or more in the population increased from 8.4 to 11.1 per cent but the number of patients from one to 80.

The reduced involvement of the spine and sacro iliac joints as well as the reduced multiplicity of bone and joint lesions may be due to the change in the patients age distribution. If both groups

are combined, thus increasing the numbers it is observed that the incidence declines with increasing age (Table 5).

Table 6 Dorsal localization in tuberculosis of the spine in different age groups

Age	No of patients	Dorsal involvement
0-19 years	35	10 (30%)
20-34 years	61	24 (45%)
35-49 years	48	27 (56%)
50-64 years	45	30 (67%)
65+ years	13	6 (46%)

The increased localization in the dorsal region in cases of tuberculosis of the spine is only probably statistically significant. The increase may perhaps be due to the change to a predominance of older patients as dorsal localization seems to become more common with increasing age. If both groups are combined the figures are as shown in Table 6.

The small number of only 13 patients 65 years old or more makes the decreased percentage in this group less convincing.

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RUPTURE OF THE DISTAL BICEPS TENDON

Report of Five Cases

LENNART HOVLIND & GÖRAN JOSEFSSON

Department of Orthopaedic Surgery, The Central Hospital Gälle, Sweden

Five cases of rupture of the distal biceps tendon are described. Three were operated on—two in the acute stage and one after 3 months—and the other two were managed conservatively. The literature on this condition is reviewed and alternative forms of treatment are discussed.

Key words: tendon rupture, biceps injury, muscle-tendon injury.

Accepted 1 III 77

Rupture of the distal biceps tendon is relatively uncommon. Various surgical methods have been described but the literature is rather sparse, particularly regarding inveterate cases. It therefore seems appropriate to present and discuss five cases that were treated at this Department in the period 1969-76.

CASE REPORTS

Case 1 A 58 year old man was treated conservatively for rupture of the distal tendon of the left biceps.

At follow up 9 years after the injury he reported lack of strength at the elbow. Examination indicated that the greater part of the biceps muscle had atrophied with considerable loss of gross muscle power in the elbow joint.

Case 2 A 55 year old man was treated conservatively for rupture of the distal tendon of the right biceps.

At follow up 4 years after the injury he reported very troublesome periodical pain located in the front of the right elbow joint and also in the right shoulder joint. Examination indicated no appreciable loss of gross muscle power in either the upper arm or the elbow, neither was supination at the elbow impaired.

Case 3 A 47 year old man experienced sudden pain in the left upper arm whilst lifting a heavy object. The diagnosis ruptured distal biceps ten-

dron was made 3 months later, at which time the gross muscle power for flexion and supination in the elbow joint was found to be impaired. In view of the patient's great subjective discomfort and his age an operation was performed. The biceps tendon, rounded off, was found in a proximal position enclosed in a synovial sack filled with synovia. The biceps muscle was reconnected to the proximal radius by means of a fascia lata graft (Kahnberg & Neisman 1973, see Figure 1).

Postoperative plaster treatment was maintained for 5 weeks. The patient went back to work 3 months after the operation, by which time elbow function was restored to normal.

Case 4 A 56 year old man experienced sudden pain in the left upper arm whilst lifting a heavy object. Rupture of the distal biceps tendon was diagnosed and an operation was performed in the acute phase, the tendon being reattached by suturing through a hole drilled in the radius. When the patient returned to work 3 months later he reported a slight loss of gross muscle power in the elbow but otherwise everything was normal.

Case 5 A 53 year old man experienced sudden pain in the left upper arm while playing handball. An operation was performed in the acute phase, the tendon being reinserted into the radial tuberosity with pull out sutures through drill holes according to Bunnell (see Figure 2). He took 3 months sick leave and had a completely acceptable result at follow up 6 months after the operation.

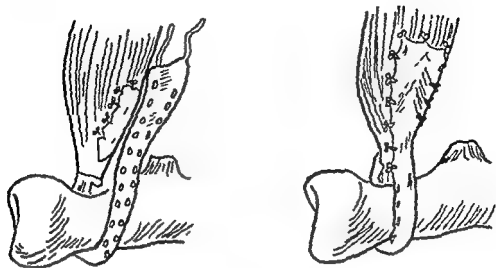


Figure 1 Repair of the biceps muscle with fascial lata (from Kalnbergs & Weissman 1975)

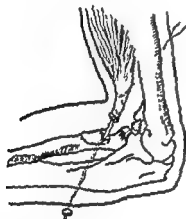


Figure 2 Reattachment of the tendon to the radial tuberosity by means of a pull out suture (from Lange 1979)

DISCUSSION

A rupture of the distal attachment of the biceps muscle is relatively uncommon of all ruptures to the biceps tendons, only about 3 per cent are reported to occur in the distal portion (Hempel & Schwenke 1974). The patients are mostly men (Postacchini & Puddu 1975) and generally around 50 years of age. This is borne out by the cases presented here. The cause is held to be a combination of de-

generative processes in the tendon and trauma (Postacchini & Puddu 1975; Hempel & Schwenke 1974). But it is noteworthy that the rupture occurs at the bony attachment and seldom leaves any tendon tissue distally.

Opinions about treatment vary. Most of the results reported in the literature concern surgical cases. Early operation carries a good prognosis. Here the generally accepted method involves reinserting the distal tendon into the tuberosity of the radius by means of holes drilled through the radius (see Figure 2).

Pull-out suture according to Bunnell or embedded suture can be used. According to Postacchini & Puddu, reinsertion may lead to radial palsy even when performed in the acute phase and they simply suture the tendon to the brachialis muscle. Kalnbergs & Weissman (1975) use a free fascial lata graft, looped round the shaft of the radius and attached at both ends to the biceps tendon (Figure 1).

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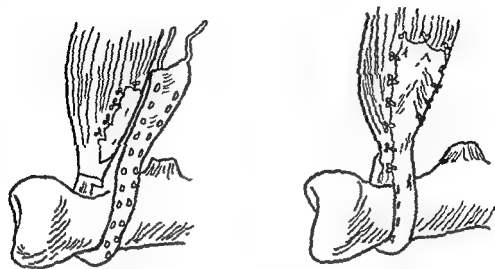


Figure 1 Repair of the biceps muscle with fascia lata (from Kalinbergs & Veisman 1975)

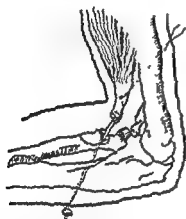


Figure 2 Re-attachment of the tendon to the radial tuberosity by means of a pull-out suture (from Lange 1967)

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Postacchini & Puddu, who reported seven cases with suture of the tendon to brachialis, considered that this simpler method gave excellent results including an entirely satisfactory restoration of

operation. Their patients included two athletes, who resumed their sport without discomfort.

In inveterate cases, surgery is an open question. In the present case (No. 3) the operation revealed a synovial sack, containing about 5 ml of synovia, around the ruptured tendon. Presumably this was partly responsible for the patient's persistent discomfort 3 months after the injury. In this instance a good result was achieved with surgery according to Kalnbergs.

Of the two patients given conservative treatment, one suffered from persistent invalidism and loss of strength in the arm, while the other had substantial subjective discomfort but little objective loss of strength.

Conclusion

Rupture of the distal biceps tendon could be operated on in the acute phase,

and the tendon re-inserted into the radial tuberosity or sutured to the brachialis muscle. An operation can be considered up to 3-4 months after the injury in persons of up to middle age, the method being either a fascia lata graft according to Kalnbergs or suture of the tendon to the brachialis muscle.

REFERENCES

- Hempel K & Schwenke K (1974) Über Abrisse der distalen Bizepssehne. *Arch orthop Unfall Chir* 79 313-319.
- Kalnbergs W K & Veisman J A (1975) Zur Röntgendiagnostik und Operativbehandlung geschlossener Verletzungen der distalen Bizepssehne. *Z Orthop* 113 956-959.
- Lange M (1962) *Orthopädisch-chirurgische Operationslehre* p. 324. Verlag von J F Bergmann München.
- Postacchini F & Paddu, G (1975) Subcutaneous rupture of the distal biceps tendon. *J Sport Med (Torino)* 15 81-90.

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OSTEOMYELITIS OF THE SPINE

SVEN COLLETT

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A study of a series of 82 cases of pyogenic osteomyelitis of the spine has shown that the clinical features at the initial stage of the disease often present such a varied picture that the correct diagnosis may easily be overlooked for a long time. Once radiographic changes are demonstrated the primary consideration in differential diagnosis is tuberculous spondylitis. Bacteriological verification by needle biopsy or surgical exploration is recommended in order to institute an adequate antibiotic therapy. Surgical evacuation is advocated in cases with extensive vertebral destruction. The majority of patients recovered within 1 year from the onset of illness. In slightly more than half of the cases the spinal lesions healed with spontaneous interbody fusion. This tendency was most pronounced in cases of cervical and upper thoracic involvement. No deaths occurred as a result of the spinal disease.

Key words: clinical course, osteomyelitis of the spine, prognosis, symptoms, treatment.

Accepted 1281177

Up to a few decades ago tuberculous spondylitis accounted for the majority of the inflammatory conditions involving the spine diagnosed in Sweden. During recent years the picture has changed and tuberculous spondylitis has become relatively uncommon whereas osteomyelitis of septic origin has increased in frequency (Figure 1). The symptomatology of pyogenic osteomyelitis of the spine has been described by several earlier authors (Wilensky 1929, Kulowski 1936, Gurr 1946, Alvik 1951, Garcia & Grantham 1960, Robinson & Iessof 1961, Ambrose et al 1966, Paus 1973, among others). It is obvious that the condition presents diagnostic pitfalls and is difficult to differentiate from other diseases, especially

tuberculous spondylitis. Whereas earlier studies of pyogenic osteomyelitis of the spine have mainly dealt with the symptomatology and diagnostic features of the disease, relatively little interest has been devoted to the clinical course and late results.

The present study was undertaken to illustrate diagnostic problems on the basis of a clinical material and to present an account of the clinical course and prognosis in pyogenic osteomyelitis of the spine.

PATIENTS

The clinical material comprises 82 cases of haematogenous pyogenic osteomyelitis of the

Number of cases

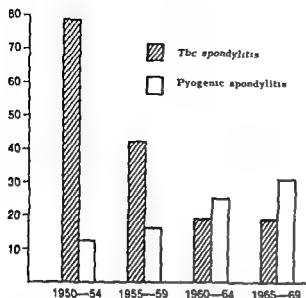


Figure 1 Distribution of cases admitted to the Orthopaedic Department, St. Göran's Hospital, and diagnosed as tuberculous spondylitis or pyogenic osteomyelitis of the spine during the period 1950-1969

spine treated at the Orthopaedic Department of St. Göran's Hospital, Stockholm, during the years 1950-1970. Cases of postoperative vertebral osteomyelitis following disc surgery are not included. The series consisted of 52 men and 31 women. As seen in Table 1, the male predominance is due to an accumulation of cases in the age groups over 40 years.

Level of spinal involvement

In eight cases the osteomyelitic changes were located in the cervical spine. In the remainder of the series, the distribution of thoracic and lumbar involvement was largely the same (Table 2).

Table 1 Age and sex distribution

Age	Men	Women	Total
0-10	1	1	2
11-20	4	7	11
21-30	4	5	9
31-40	4	4	8
41-50	7	3	10
51-60	12	2	14
61-70	13	7	20
71-80	4	2	6
over 80	2	0	2
Total	51	31	82

Table 2 Site of vertebral osteomyelitis

Level of spinal involvement	Number of cases
Cervical	8
Thoracic	32
Thoracolumbar	6
Lumbar	27
Lumbosacral	8
Thoracic and lumbar	1
Total	82

In the vast majority of cases (75 patients) two adjacent vertebral bodies were affected. In three cases changes were present in only one vertebral body, in two cases in three, and in two cases in four adjacent vertebral bodies. In no case was there any involvement of the arches or spinous processes.

Primary focus

A probable source of bacterial infection could be identified in 31 cases. In 19 of them symptoms developed as a direct sequel to a urinary tract infection (Table 3). Forty-nine patients were unable to report any previous infection likely to have a connection with their spinal symptoms.

The interval between the primary infection and the onset of spinal symptoms ranged from 1 week to 3 months, but in the vast majority of cases the interval was between 2 and 3 weeks.

Ten patients (12 per cent) in the total series had diabetes mellitus.

CLINICAL FEATURES

In all but seven cases the onset of illness was acute or subacute and fever and pain were the two symptoms dominating the initial stage. Ten of the patients were hospitalized in an isolation unit with a diagnosis of obscure pyrexia. Since back pain in these cases was overshadowed by

Table 3 Primary focus

Urinary tract infection	19
Respiratory tract infection	8
Skin infection	4
Cholecystitis	2
Unknown	49
Total	82



Figure 2 Radiographs of a male 58 years of age A Tomogram 2.5 months after onset shows narrowing of the space between L2 and L3 and destruction in these vertebral bodies No gibbus can be seen A thin layer of new bone is visible anteriorly B Two years later the bone structure is partly normal A bridge of bone is visible anteriorly there is a bridge of bone between L2 and L3

the fever and general systemic reaction the correct diagnosis was frequently considerably delayed

Most of the patients however had a severe dull backache during the first 1 or 2 months which was aggravated by movement Segmentally radiating pain was very common and frequently led to an erroneous initial diagnosis Two of the cases of cervical osteomyelitis for instance were diagnosed as myocardial infarctions and admitted to an internal medical unit In cases of osteomyelitis involving the thoracic or lumbar spine abdominal pains frequently dominated Eleven patients were referred to a general surgical unit as acute abdominal cases and in three cases laparotomy was performed (in one case for suspected ileus and in two cases for suspected appendicitis) In cases of osteomyelitis involving the lower lumbar spine sciatic pains in one or both legs were not uncommon

Objective findings at the acute stage were muscle spasm and rigidity in the affected spinal region Distinct percussion tenderness over the spinous processes of the affected vertebrae was an almost constant finding Sciatic pains were not at any time associated with signs of neurological deficit Four patients (5 per cent) in the total series developed paraplegia after an interval of 2 4 5 and 8 weeks respectively from the onset of illness

Laboratory findings

In most cases ESR was strongly elevated during the first months of the disease In 31 cases the highest recorded value exceeded 100 mm/h and in 62 cases 50 mm/h

The antistaphylococcal titre was determined in 76 cases and was increased (more than 20 IE) in 36 patients In 12 cases peak values of more than 160 IE were recorded

Radiographic findings

The earliest radiographic changes in the majority of cases seen from 2 to 8 weeks after onset were paravertebral soft tissue swelling narrowing of the disc space and superficial destruction of the end plates of adjacent vertebral bodies (Figures 2 and 3)

DIAGNOSIS

The diagnosis was in 20 cases confirmed by bacterial culture of specimens obtained either directly from the spinal focus of infection or from a paravertebral abscess In ten cases the specimen was obtained by needle biopsy and in the remaining ten cases at operation In most of these cases additional histological examination was performed and showed a non specific inflammation

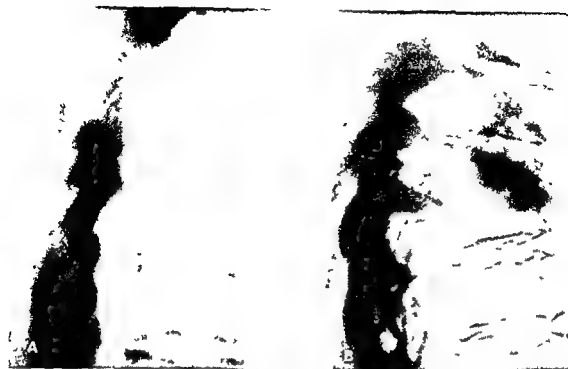


Figure 3 Radiograms of a male, 52 years of age A Tomogram 2 months after onset shows extensive destruction in the adjacent parts of Th7 and Th8 and a slight gibbus B Seven months after onset the intervertebral space is bridged by bone, but the bone structure is still irregular

In another 17 cases the diagnosis was confirmed only by histological findings after routine bacterial culture, tubercular culture and guinea-pig tests had proved negative.

In slightly more than half of the cases (45 patients) histological proof and bacterial culture from the osteomyelitis region was lacking, and in these cases diagnosis was based on the clinical features and the appearance of the radiographic changes. Four of the patients in this group had a positive blood culture, and in another five cases, which in all likelihood were secondary to a urinary tract infection, a positive urine culture was noted in the records.

Needle biopsy was done in 41 cases (4 cervical, 18 thoracic and 19 lumbar) and yielded positive results in 20 cases (positive culture and/or histological findings).

Bacteriology

The infecting organism could be identified in 24 cases (Table 4). All but two of the 18 patients with spondylitis caused by *Staphylococcus aureus* had an increased antistaphylolysin titre. The primary source of infection in these cases was the urinary tract in four patients, the respiratory tract in four patients, a skin infection in three patients, and cholecystitis with a subphrenic abscess in one case. In the remaining six cases no primary focus could be established.

Table 4 Causative organism

<i>Staphylococcus aureus</i>	18
<i>Staphylococcus albus</i>	1
<i>Escherichia coli</i>	4
<i>Proteus</i>	1
Total	24

TREATMENT

Surgical exploration was performed in 20 cases. In 15 cases osteomyelitis involved the thoracic spine and exposure was made by costotransversectomy in all of these cases. In the other five cases the lumbar spine was the site of the osteomyelitic lesion and exposure was made retroperitoneally. The purpose of this operation was twofold. In the first place it permitted the diagnosis to be verified in cases with inconclusive clinical and radiographic findings and provided the material for bacterial culture to guide the selection of the appropriate antibiotics for continued treatment. Secondly in cases with extensive destruction and suspected paravertebral abscesses surgery was undertaken with the aim of speeding up healing by removing infectious tissue. In these cases, a tuberculous origin was often suspected. In two cases the in-

dication for surgery was paraplegia developing as a sequel to osteomyelitis in the thoracic region.

The time between the onset of illness and operation varied between 6 weeks and 2 years. In ten cases operation was performed within the first 4 months and in all but two cases within 9 months of onset. In eight of the operated cases the spinal lesion was found to be at the healing stage and the operation was considered to have had diagnostic value only. In 12 cases such a large amount of infectious tissue was removed

The remainder had oedema or merely a diffuse swelling of the paravertebral tissues.

Posterior fusion was performed in two cases. One of these patients had an atlanto axial osteomyelitis resulting in complete destruction of the odontoid process and instability between the first and second cervical vertebrae. A detailed report of this case has been published earlier (Ahlbäck & Collert 1970). In the second case posterior fusion at the level of the eleventh and twelfth thoracic vertebrae was prompted by an unusually protracted course with intractable pain.

No serious postoperative complications occurred.

Antibiotic treatment

Fifty three patients were treated with antibiotics over a continuous period of more than 1 week. Fifteen of these patients were treated for a period of 1 to 3 months and 25 patients for more than 3 months. In 29 cases no antibiotic treatment was felt to be necessary.

Immobilization

The duration of bedrest has been dictated by the patient's subjective symptoms even though some caution with respect to mobilization has been observed in cases with extensive vertebral destruction. A plaster bed was used in only eight cases.

CLINICAL COURSE

In about one third of the patients with an acute or subacute onset general malaise and pain were so pronounced during the first 1 or 2 months that they were largely confined to bed. In the remainder of the series the acute stage was of shorter duration, sometimes less than 1 week. This was followed by a gradual improvement with considerable individual variations in the

rate of improvement. In assessing the activity of the osteomyelitic process, ESR was used as a guide and on the whole this also reflected the patients' subjective symptoms. Occasional brief periods of exacerbation during which the patients' complaints were aggravated and a slightly elevated temperature was also noted in some cases were not uncommon. Peak ESR and ASTA readings were usually recorded 1 to 2 months after onset.

In those patients (64 cases) in which the interval between the onset of illness and normalization of ESR readings (< 15 mm/h) could be determined a median value of 35 months (range 2-6 months) was found for cervical, 6 months (range 1-12 months) for thoracic and 7 months (range 1-30 months) for lumbar osteomyelitis.

No appreciable difference was noted in the length of the clinical course between patients with increased antistaphylococcal titre and the remainder of the series. Peak ESR readings recorded in cases of "Staphylococcus osteomyelitis" were significantly higher than in the remainder of the series however.

Of the two patients with total paraplegia, in whom operation was performed one case made a complete recovery within 9 months of operation. The other patient who had a history of total paraplegia for 3 months prior to operation improved postoperatively but 2 years later still had a partial spastic paraparesis. Two other patients who were partially paraplegic were treated conservatively and made a recovery 5 and 20 months after onset, respectively.

RESULTS

Sixty-five patients with a follow-up period of more than 2 years (average 2 1/2 years) were available for follow-up examination. Of the remainder of the series, eight patients had died and nine could not be traced.

Subjective symptoms. Sixty-one patients were symptom free or had symptoms of such a mild nature that their activities were not appreciably restricted.

Two patients reported backache of such severity as to occasion periodical sick leave.

One patient had been granted a disability pension because of his back symptoms and one patient still had a partial spastic paraparesis.

Three patients had had suspected recurrences with an acute onset of back pain, fever and ESR over 100 mm/h. Radiographic examination of the back failed to demonstrate any destructive process going on in the skeleton.

Objective findings. Clinical examination of the back showed a marked gibbus at the level of osteomyelitic involvement in two cases.

Radiographic findings. The radiographic evidence showed all spinal lesions to be healed at follow-up examination. In 33 of the 56 cases included in this follow-up examination, total or partial bony fusion between the involved vertebrae was noted. All six of the cervical lesions and 22 of the 20 thoracic lesions had healed by interbody fusion, but this was found in only five of the 21 cases of lumbar involvement. When interbody fusion had not occurred, the usual finding was a narrowed disc space with some irregularity in the end plates, but with normal bone structure (Figures 2 and 3).

DISCUSSION

The clinical features of pyogenic vertebral osteomyelitis in its initial stage may present a highly varied picture. Referred pain is common and easily tends to lead to an erroneous diagnosis, as evidenced by the present series. This risk appears to be greatest when the disease involves the lower region of the thoracic spine or the upper region of the lumbar spine. At these levels the clinical picture is often dominated by abdominal pains which may suggest an acute abdominal condition. In urosepsis complicated by vertebral osteomyelitis the symptoms—pain and fever—may for a long time be masked by or be attributed to the primary infection. Spinal changes may be seen as early as 2 to 3 weeks after the onset of symptoms, but in other cases 2 or 3 months may pass before any changes can be demonstrated. In the

present series the correct diagnosis was considerably delayed in several cases by negative radiographs during the first few months.

Once radiographic changes have been demonstrated, the primary consideration in differential diagnosis is tuberculous spondylitis. That pyogenic osteomyelitis of the spine is frequently erroneously interpreted as being of tuberculous origin is demonstrated by the present series, in which no less than 28 of the 82 patients were referred to this department with a diagnosis of tuberculous spondylitis. In 11 of these cases antituberculous chemotherapy had been initiated. The differential diagnosis may sometimes present difficulties, but in our experience many of the clinical and radiographic findings in pyogenic osteomyelitis of the spine are sufficiently characteristic for the correct diagnosis to be established in the majority of cases once radiographic changes can be detected (Ahlback et al 1969, 1973).

Malignancy was suspected in a few cases, which radiologically were characterized by a destructive process wholly or predominantly confined to one single vertebra. As a rule, however, differential diagnosis in these cases has presented little difficulty.

In contrast to tuberculous spondylitis reports on surgical treatment for pyogenic osteomyelitis of the spine are very scarce. Most authors consider immobilization and antibiotics sufficient treatment (Garcia & Grantham 1960, Robinson & Lessof 1961, Pollack et al 1964, Weber 1965, Ambrose et al 1966, Griffiths & Jones 1971). Riskó et al (1962), on the other hand, advocate radical evacuation in all cases to ensure reliable healing. Even though the end result is the same, we feel that evacuation of foci of infection and abscesses may speed up healing in cases with radiographic evidence of extensive destruction and marked paravertebral swelling. Our experience

suggests that such operations will be of greatest value when performed within 3 to 4 months of onset.

The incidence of paraplegia as a complication to pyogenic osteomyelitis of the spine varied between 4.5 and 13 per cent in reports published during recent years (Ahlik 1951, Weber 1965). In our series the incidence was 5 per cent. Conservative management is advocated by most authors also in the treatment of this complication and reports on the results of surgical treatment are on the whole lacking. From our experience of surgical treatment of paraplegia secondary to tuberculous spondylitis, we feel that anterior decompression by thoracotomy, or in some cases anterolateral decompression by costotransversectomy, is indicated in paraplegic cases (Felländer 1975). Even though conservative treatment may also lead to the desired result, anterior or anterolateral decompression is in all likelihood a quicker and more reliable way of achieving restitution.

The effect of antibiotic treatment is difficult to assess. However, we may reasonably assume that early and adequate drug therapy will prevent or minimize progress of the destructive changes in the affected vertebrae and thus promote a faster recovery. This naturally presupposes that a bacteriological diagnosis is obtained at an early stage of the disease. Our experience indicates that it is

et al (1966). In our series no deaths resulted from the disease. With regard to the duration of illness and clinical course, Garcia & Grantham (1960) report that the average time required to return to work in their series was 12 months from onset, and that spontaneous interbody fusion was the rule. Robinson & Lessof (1961) noted that there is, in some cases at least, a tendency to spontaneous recovery, but the disease may remain chronic or recur after months or years. Weber (1965) found recurrences in 13 per cent of his cases. In our series the clinical course was fairly similar in the majority of cases with an apparently strong tendency to spontaneous healing. A noteworthy finding is that the period of illness tended to be shorter and interbody fusion more common in cases of cervical involvement than when other levels were involved. The risk of recurrence would seem to be small. In our series suspected recurrences were noted in three cases (1 per cent).

Earlier authors (Felländer & Lindberg 1966, Defiore et al 1970) have shown that scintimetry may be of value in determining whether or not a spondylitic process is active. In our series the method was adopted for that purpose in a limited number of cases, but it cannot be used as a diagnostic tool to differentiate pyogenic osteomyelitis of the spine from tuberculous disease or cancer.

REFERENCES

- Ahlik, S. & Collert, S. (1970). Destruction of the odontoid process due to atlanto axial pyogenic spondylitis. *Acta radiol* (Stockh) 10: 394-400.
- Ahlik, S., Collert, S. & Felländer, V. (1973). Osseus bakterieell spondylit. *Scand J Läk* 70: 2234-2236.
- Ahlik, S., Collert, S. & Lindberg, L. (1969). Non specific spondylitis. *Acta orthop scand* 40: 678.
- Ahlik, S. (1951). Chronic pyogenic spondylitis—tuberculous spondylitis. *Acta orthop scand* 21: 227-242.

varying the drug if no immediate response is effected.

The clinical course and late results have been treated very summarily and in completely in earlier reports on pyogenic osteomyelitis of the spine. The high mortality rate recorded in the preantibiotic era (Chulonski 1936) has in more recent studies been reduced to less than 10 per cent (Garcia & Grantham 1960, Athroes

- Ambrose G B, Alpert M & Neer, C S (1966) Vertebral osteomyelitis. A diagnostic problem *J Amer med Ass* **197**, 619-622
- Defiore J C, Lindberg L & Ranawat, N H (1970) ⁸⁵Strontium scintimetry of the spine *J Bone Jt Surg* **52 A**, 21-38
- Fellander, M (1975) Paraplegia in spondylitis. Results of operative treatment *Paraplegia* **13** 75-88
- Fellander, M & Lindberg L (1966) Clinical use of radiostrontium in evaluation of spondylitis *J Bone Jt Surg* **48 A** 1585-1606
- Garcia A & Grantham A (1960) Hematogenous pyogenic vertebral osteomyelitis *J Bone Jt Surg* **42 A** 429-436
- Griffiths H F D & Jones D M (1971) Pyogenic infection of the spine *J Bone Jt Surg* **53 B** 383-391
- Guri J P (1946) Pyogenic osteomyelitis of the spine *J Bone Jt Surg* **28** 29-39
- Kulowski J (1936) Pyogenic osteomyelitis of the spine *J Bone Jt Surg* **18** 343-364
- Paus, H (1973) Tumour tuberculosis and osteomyelitis of the spine. Differential diagnosis aspects *Acta orthop scand* **44** 342-339
- Pollack N, Spinner, M & Richman R (1966) Hematogenous pyogenic spondylitis *VI S J Med* **64** 2870-2875
- Ruskó T, Gáski I & Novoszel T (1962) Leb- die chronische Wirbelsäulenosteomyelitis bei Erwachsenen *Z Orthop* **96** 448-456
- Robinson B H B & Lessof, M H (1961) Osteomyelitis of the spine *Guy's Hosp Rep* **111** 303-318
- Weber R (1965) Considérations sur l'ostéomyélite vertébrale *Rev Chir Orthop* **51** 273
- Wilensky, A O (1929) Osteomyelitis of the vertebrae *Ann Surg* **89** 561-570

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LIMB BLOOD FLOW IN THE PRESENCE OF A TOURNIQUET

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There is little accurate data on the blood flow to a limb distal to the site of application of a tourniquet. This has been studied in Rhesus monkeys with 50 μ diameter microspheres labelled with ^{51}Cr and by the washout of ^{22}Na injected into the tissues. One limb was exsanguinated and the circulation occluded with a pneumatic tourniquet and the opposite limb used as a control. The results show that blood flow to the occluded limb is less than 1 per cent of the flow to the control limb. It is unlikely that this relieves the ischaemia in any way as has been suggested.

Key words: blood flow, ischaemia, limb, tourniquet.

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It has been suggested that despite the application of a tourniquet to the proximal portion of the upper or lower limb, as is the practice in orthopaedic operations, blood may flow into the limb by way of the medullary canal. This may result after 30 minutes in an ooze into what was previously a dry field (Furlow 1971). Measurements of this blood flow have been made both experimentally in rabbits and at operation and the amount of blood by passing the tourniquet has been recorded as varying from 1-26 per cent of the total flow to the unoperated limb (Spira et al 1965). This circulation has been described as a factor in relieving the ischaemia produced by the tourniquet and to be of help in prolonging the period it is safe to keep it in place.

In order to clarify the situation, an investigation has been carried out on Rhesus monkeys. These animals were chosen because of their anatomical similarity to the human subject. The ques-

tions posed were: How much blood reaches the distal end of a limb with a tourniquet occluding the arterial inflow, and under these conditions, what is the extent of venous return?

MATERIAL AND METHODS

In the first series of animals, radioactive microspheres about 50 μ in diameter, were used to study blood distribution because they are almost completely extracted from the blood as it passes through the capillary bed (Wagner et al 1969). The second series of animals was studied using ^{22}Na , plus the local clearance of a diffusible tracer, injected into tissue. At low flow rates, the washout rate provides an index of the blood perfusion (Kety 1949). ^{22}Na was also used to estimate the venous return from the limb.

Rhesus monkeys were anaesthetised using nitrous oxide, halothane and oxygen. The limb

of mercury

either up

intra arterial blood pressure in the aorta in Rhesus monkeys have shown a range similar to

man 175-110/95-65 mm of mercury with an average of 134.76 (Werdegær et al 1964) and 136-117/84-71 mm of mercury (Forssyth & Bairreuter 1967)

In the first series of animals, a catheter was passed into the left ventricle under radiological control and 10^4 - 10^7 particles (Tracer Sephadex 50 Pharmacia, Uppsala, Sweden) labelled with ^{61}Cr (Radio Chemical Centre, Amersham) in 0.3-1.0 ml were injected over a period of 20-40 seconds. The catheter was flushed with 5 ml of isotonic saline and a bolus of 5 ml of radiopaque contrast medium was used to check that the catheter was still in place and therefore that material from the catheter was well mixed before entering the aorta.

The activity in the syringe was measured before and after injecting the particles and the activity in the catheter was measured after it had been withdrawn. The external measuring system consisting of two 7.5 diameter \times 5 cm thick sodium iodide scintillation detectors with 5 cm thick lead collimators was used to measure the activity in the extremities of the monkey as well as the injected dose. The effects of background from the trunk of the monkey was reduced by fixing a lead screen between it and the detectors, passing the limb through a 5 cm wide slot in the screen. After each measurement, a background reading was taken with the limb moved to a position just outside the lead screen. In each experiment the fraction of cardiac output to the region of the limb with the tourniquet was compared with a similar region on the opposite limb as a control. Measurements were made on six animals, i.e. five hands, five forearms, three feet and three lower legs.

Two animals were sacrificed after the particles had been injected. In these experiments an arm and a leg were occluded with tourniquets and the catheter was passed via the carotid artery. When external measurements were complete the animal was dissected. The hands, feet, lower leg muscles, forearm muscles, tibiae, lungs, liver, spleen and kidneys were placed in sealed plastic pots and then measured in a bulk sample counter (Cronquist et al 1975). This consisted of two 12.5 cm diameter \times 5 cm thick sodium iodide detectors completely surrounded by lead 5 cm thick. The activity of the syringe before and after injection and the activity of the catheter were also measured in this detector system. In one animal, the upper and lower halves of the humerus and femur were counted separately. Samples of muscle (about 5 g) were placed in stoppered bottles with formalin, balanced weights of the shaft of the tibiae were placed in similar bottles and the samples counted using a gamma ray counter incorporating a well type sodium iodide crystal (L&B Wallac). The con-

trol samples were counted until 10 000 counts had been accumulated and the samples from the limbs which had been occluded by tourniquet were counted for 1,000 seconds.

The sodium washout and venous return from a limb with an occluding tourniquet was studied in two animals. Approximately 15 μCi of ^{22}Na was injected into the muscle of the leg distal to the tourniquet. One of the 7.5 cm diameter sodium iodide detectors was placed over the site of injection and the activity was monitored using a ratemeter and chart recorder as well as a scaler and timer. Blood samples were taken from the inferior vena cava at regular intervals for 1 hour. The detector was then transferred to a similar region of the control limb and approximately 15 μCi of ^{22}Na was injected into the corresponding muscle. The activity was monitored until it fell to about half of its initial value, whilst blood samples were taken at frequent intervals.

The detector was returned to the limb with a tourniquet, the tourniquet released, and the activity monitored whilst blood samples were taken. This experiment was repeated on one further animal to investigate the possible return of blood by way of the medullary circulation. In both limbs the ^{22}Na was injected into the medullary cavity of the distal end of the femur through a small hole drilled through the articular surface of the distal surface of the femur.

RESULTS

The average of 17 external measurements of control feet, hands, lower legs and forearms was 1.7 per cent of the injected dose with a standard deviation of 1.2 per cent. The activities of the corresponding regions of the limbs with tourniquets were expressed as a percentage of the control regions and gave a mean of 3.1 per cent with a scatter from 0.3 to 15 per cent.

The radioactivity of parts of limbs that were removed for counting in the bulk sample counter are summarised in Table 1. The results of measurements made in the well-type counter are shown in Table 2, where only the percentage of an equivalent weight from the control side could be calculated.

In Table 3, the activities of the major organs are used to calculate the per-

Table 1 Dissected animals Microspheres

Activity of parts of the limb with tourniquet as a percentage of the count rate from the corresponding part of the control limb

Animal no	1	2
Time from injection to death	5 min	1 h 30 min
Hand	0.05	0.24
Arm muscle	0.4	1.16
Foot	0.01	0.69
Leg muscle	0.3	0.55
Tibia	0.01	0.76
Radius		0.76
Mean	0.15	0.69
Standard deviation		0.3
Upper humerus		87
Lower humerus		8
Upper femur		82
Lower femur		38

centage of cardiac output reaching the individual organs. The figures are compared with those obtained by Hoffbrand & Forsythe (1969) and Forsythe et al (1968).

Table 2 Dissected animals Microspheres

Samples counted in well type counter. Count rate of samples from limb with tourniquet as a percentage of control

Animal no	1	2
Arm muscle	0.5	0.96
Leg muscle	0.1	0.26

The external measurements of ^{22}Na are in Table 4. The values of the half periods during the period of occlusion suggest a

Table 3 Dissected animals Microspheres Major organs of the body

Animal no	1		2		Earlier results Forsyth et al (1968) (n = 13) Hoffbrand & Forsyth (1969) (n = 42)					
	$\% \text{ body weight}$	$\% \text{ dose}$	$\% \text{ body weight}$	$\% \text{ dose}$	$\% \text{ body weight}$	SD	$\% \text{ dose}$	SD	$\% \text{ dose}$	SD
Liver	42	81	31	86	44	0.8	46	3.8	48	3.2
Spleen	0.8	2.6	0.6	8.3	0.2	0.1	1.9	1.2	2.5	1.4
Kidneys	1.2	21.0	1.1	6.2	0.7	0.1	12.3	3.1	15.7	3.7
Lungs	3.1	6.1	2.9	4.3	1.1	0.7	0.5	0.6	0.9	0.9

Note: Forsyth et al (1968) and Hoffbrand & Forsyth (1969) measured unanaesthetised monkeys that were sitting in a restraining chair. The animals that we studied were anaesthetised and supine and this may account for the difference in lung uptake.

Table 4 Washout of ^{22}Na

Animal no	3	4	5
Site	Leg muscle	Leg muscle	Femur
Tourniquet ($\text{T}\frac{1}{2}$)	50 h	Zero slope	25 h
Control ($\text{T}\frac{1}{2}$)	23 min	11 min	24 h
Control $\text{T}\frac{1}{2}$ as $\% \text{ tourniquet } \text{T}\frac{1}{2}$	0.8	0	9.5
After release ($\text{T}\frac{1}{2}$) (1)		2.8 min	6.3 min
After release ($\text{T}\frac{1}{2}$) (2)		14.1 min	3.9 h
Control $\text{T}\frac{1}{2}$ as $\% \text{ tourniquet } \text{T}\frac{1}{2}$		78	62
The half -	-	-	-
Your	-	-	-
respo	-	-	-
imme	-	-	-

log counts/second against time
control an injection into the cor
after release (2)' are the slopes
when the limb had recovered from hyperaemia

muscle blood flow of less than 1 per cent of the control. No measurements were possible after release of the tourniquet on animal No. 1, because it went into a state of shock.

Table 5 Blood samples taken during washout of ^{22}Na

Animal no	3	4	5
Tourniquet			
counts/1000s	391	378	390
standard deviation	32	16	13
no of samples	4	5	7
background	366	372	333
Control			
peak $\times 1000$	25.4	21.5	5.9
at (min)	10	2	0.5
plateau $\times 1000$	5.6	5.8	3.6
at (min)	25	31	27
Release			
peak $\times 1000$		24.1	12.5
at (min)		2	2
plateau $\times 1000$		7.8	4.3
at (min)		21	28

Table 5 gives the measurements on blood samples. There was no detectable return of isotope from intramuscular injection to the leg of the animal but there was a significant return, less than 0.1 per cent of the control, from the distal end of the femur. The slow flow that carried away the isotope must therefore have been into the lower part of the limb. When isotope was injected into the control limb, a peak of activity was detected in blood samples and this was followed by a slowly decreasing level. This 'plateau' level can be compared with 2 standard deviations of the background count in setting an upper limit to the venous return.

DISCUSSION

Measurements of the radioactivity of isolated segments of the sacrificed animals suggest that all *in vivo* radioactivity

measurements gave results which were too high. This was probably due to the difficulty in screening the occluded limb from the activity in the rest of the body. When 10^6 particles were injected very few reached the limb with the tourniquet. For example, in the isolated foot of animal No. 1 the number of particles was of the order of 10, whilst in the samples of muscle, there were less than 5. For this reason long counting times and low background do not substantially improve the accuracy of measurement.

Buckberg et al. (1971) showed that statistical errors due to the random distribution of particles are an important source of error when the number of particles present is less than 500. In order to produce this number in the limb to which tourniquets had been applied in further experiment, approximately 10^6 particles were injected into the left ventricle. The results of this experiment confirm that the blood flow to the limb with a tourniquet is small and does not exceed 1 per cent of that of the control limb.

The experiments with ^{22}Na confirm that there is negligible venous outflow past the tourniquet and that the perfusion of muscle distal to the tourniquet is very small. The measurements on the muscle consisted of digital counts of approximately 40,000, so that the standard deviation due to statistical fluctuation was 0.5 per cent. The series of counts remained within ± 2 standard deviations on both animals for 1 hour. A least squares fit to the set of digital counts gave a slope corresponding to a half period of 50 hours on animal No. 3 and zero slope on animal No. 4. This makes the upper limit of the blood perfusion about 0.7 per cent of the unoccluded value.

The blood samples confirmed that no blood was detected leaving the limb with a tourniquet, in this case the minimum detectable activity from the limb with a

tourniquet was 2 standard deviations (10 per cent) of the background. The upper limit of venous return from the limb with a tourniquet was therefore about 0.2 per cent of that from the control limb.

When isotope was injected into the distal end of the femur, the venous return was still less than 1 per cent of that from the control limb.

The amount of blood flow detected here is not likely to be significant for the relief of ischaemia and the limb is virtually isolated from the circulation. The result obtained does not totally differ from those of Spira et al. (1965) because of the difference in technique. These workers injected ^{51}Cr labelled red blood cells and compared tourniquet and control limbs after 3 hours. If less than 0.5 per cent of cardiac output reached the limb with a tourniquet there could be a build up of activity to the levels they reported particularly if venous outflow was completely stopped.

In our experiments the uptake of microspheres was measured from one passage so that the input to the limb with a tourniquet consisted of a bolus rather than a continuous supply. Under these conditions the number of microspheres detected is directly related to the blood flow to the limb.

Conclusions

- 1 The amount of blood reaching the limb distal to a tourniquet is less than 1 per cent of the blood flow to the control limb.
- 2 The venous return is less than 0.2 per cent of that of the control limb.
- 3 The limb with a tourniquet is virtually isolated from the circulation so the amount of blood reaching the tissues is not likely to be significant for the relief of ischaemia.

ACKNOWLEDGEMENTS

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REFERENCES

- Buckberg G D, Luck J C, Payne D B, Hoff man J I E, Archie J P & Fidler D E (1971) Some sources of error in measuring regional blood flow with radioactive microspheres. *J appl Physiol* 31 598-604.
- Cronquist A H, Mackenz J & Smith T (1975) A high resolution bulk sample counter with variable geometry. *Int J appl Radiat* 26 89-91.
- Forsyth R P & Basreuther R (1967) Systemic arterial blood pressure and pulse rate in chronically restrained Rhesus monkeys. *Amer J Physiol* 215 1461-1463.
- Forsyth R P, Nies A S, Wyler F, Neutze J & Weigman K L (1968) Normal distribution of cardiac output in the unanesthetized restrained Rhesus monkey. *J appl Physiol* 25 736-741.
- Furrow L T Jr (1971) Cause and prevention of tourniquet ooze. *Surg Gynec Obstet* 132 1069-1072.
- Hoffbrand B I & Forsyth R P (1969) Validity studies of the radioactive microsphere method for the study of the distribution of cardiac output, organ blood flow and resistance in the conscious Rhesus monkey. *Cardiovasc Res* 3 426-432.
- Kety S S (1949) Measurement of regional circulation by the local clearance of radioactive sodium. *Amer Heart J* 38 321-328.
- Spira E, Karznelson A, Czerpnak P & Nikolajkov A (1965) Osseous blood circulation in the lower limb. *Israel J med Sci* 1 573-578.
- Wagner H N Jr, Rhodes B A, Sasaki Y & Ryan J P (1969) Studies of the circulation with radioactive microspheres. *Invest Radiol* 4 374-386.
- Werdegard D, Johnson D H & Mason J W (1964) A technique for continuous measurement of arterial blood pressure in unanesthetized monkeys. *J appl Physiol* 19 519-521.

ENDOPROSTHESIS AS TREATMENT FOR NECROSIS AND PSEUDARTHROSIS AFTER TRANSCERVICAL FEMORAL FRACTURES

A Clinical Review

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This report concerns 105 patients who developed painful necrosis or pseudarthrosis after nailed transcervical femoral fractures and were treated by Moore's arthroplasty. The mean age at the time of secondary arthroplasty was 68 years, the operation being performed on average 2 years after the fracture and nailing. The mortality within 6 weeks of operation was 3 per cent. Complications not producing late sequelae were seen in 11.4 per cent of cases, and complications producing late sequelae occurred in 5.7 per cent. At the follow up examination 2-10.8 years after arthroplasty (mean 3.7 years), 37 per cent of the patients were completely free from pain, and the functional result was acceptable in 91 per cent. The remaining 9 per cent had other debilitating illnesses. The results are compared with other reports in the literature.

Key words: femoral neck fractures, pseudarthrosis of femoral neck, necrosis of femoral head, hip joint, joint prosthesis, arthroplasty, postoperative complications, follow-up studies.

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According to many reports, the reduction and nailing procedure for fracture of the femoral neck is followed by complications in up to 50 per cent of cases (Tillberg 1976). Pain is not always present despite pseudarthrosis or necrosis of the femoral head, and some authors claim that only about half of these patients suffer any discomfort (Huerfion et al 1965). Thus roughly one patient out of every four with a nailed femoral neck complains of symptoms requiring further treatment (Johansson 1964). The usual management is hemiarthroplasty using a Moore or Thompson endoprosthesis. Many reports have appeared of

the late results of arthroplasty in general, but little has been published solely on the subject of secondary arthroplasty.

PATIENTS AND METHODS

During the period 1963-1968, 105 patients with pseudarthrosis or necrosis of the femoral head after nailing of femoral neck fractures were treated by arthroplasty at the Orthopaedic Hospital Hälsoand Sweden (Table 1). The patients were referred from several general surgical clinics and the true incidence of complications among the total number of femoral neck fractures could therefore not be calculated. The age distribution of the patients at the time of hemiarthroplasty is given in Figure 1.

The indications for arthroplasty were cruci-

ating pain on weight bearing and night pain disturbing sleep. The incidence of slipped nail pseudarthrosis and necrosis of the femoral head is shown in Table 2. The group slipped nail includes early complications where pseudarthrosis or necrosis of the femoral head could not be confirmed by x ray whereas pseudarthrosis includes later complications with no signs of necrosis of the femoral head. The group necrosis of the femoral head includes patients with x ray signs of necrosis and also some with both necrosis and pseudarthrosis. The incidence of late sequelae after nailing according to Pauwels grouping (Pauwels 1935) is shown in Table 3.

Table 1 One hundred and five patients treated by Moore arthroplasty because of late complications of nailing

Age (years)	mean	68
	range	44-87
Sex	women	89
	men	16
Side	right	55
	left	50
Follow up time (years)	mean	3.7
	range	2-8

Table 2 Indications for Moore arthroplasty

	No of patients
Slipped nail	10
Pseudarthrosis	41
Necrosis of femoral head	54
Total	105

Table 3 Classification of the patients according to Pauwels groups

Group	I	II	III
Slipped nail and pseudarthrosis	0	16	35
Necrosis of femoral head	0	22	32
Total	0	38	67

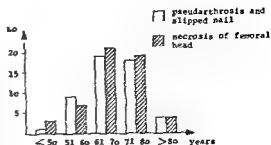


Figure 1 Age distribution

divided at the appropriate angle when possible one cm above the lesser trochanter in order to avoid shortening the leg. The capsule and lateral rotators were also sutured. To start with the patient was kept in bed for a week after operation. As more experience was gained, weight bearing and physiotherapy including walking exercises were started the day after operation. The patient was discharged from hospital as soon as everyday activities were possible or on average 5 weeks after operation (range 3-12 weeks). Fifty eight patients remained in hospital for less than 6 weeks.

Of the 105 patients operated upon three died within 6 weeks of operation. Subsequently a further 15 patients died from causes unrelated to the operation. Thus at the time of review 87 patients were available and all were clinically examined by the author 2 to 8 years after operation (Table 1).

RESULTS

Complications during and after operation are shown in Table 4. The figures for postoperative mortality (3 per cent) refer to all patients dying within 6 weeks of operation. Other complications are subdivided into those producing and those not producing late sequelae. The former necessitated removal of the prosthesis in two patients because of deep infection. Mechanical loosening accompanied by pain occurred in four patients, after 18 months to 3 years, and they were successfully treated with a McKee Farrar prosthesis.

The interval between nailing and arthroplasty for the whole group was, on average, 24 months (range 4-120 months). For slipped nails the delay

Moore's self locking prosthesis was employed in every case using Moore's southern approach technique (Moore 1957). The femoral neck was

averaged 5 months, for pseudarthrosis 21 months, and for the group 'necrosis of the femoral head' 29 months. During this period most of the patients had experienced a great deal of pain and discomfort, and had needed hospital care most of the time.

Table 4 Postoperative complications

	No	Per cent
Mortality	3	3
Cardiac	2	
Pulmonary	1	
No late disability	12	11.4
Fracture during operation	3	
Postoperative dislocation	1	
Clinical thromboembolism	3	
Haematoma	3	
Superficial infection	1	
Cardiac infarction	1	
Late disability	6	5.7
Deep infection	2	
Separation of prosthesis with pain	4	

Table 5 shows the incidence of pain at the time of review. Thirty-seven per cent of patients were free from pain. Intermittent pain on weight-bearing means slight or moderate pain after walking several hundred metres. Intermittent spontaneous pain means pain at rest not disturbing sleep, sometimes claimed to be caused by a change in the weather.

Before the hemiarthroplasty none of the patients were able to work, and many needed institutional care. The patients' occupations or activities at the time of the follow-up examination are given in Table 6. Of the 87 patients, 57 were old age pensioners, so their only work was household duties or taking care of themselves, even though some would have been capable of more. Eight were in nursing homes, six because of senile dementia or cerebral lesions, one with rheumatoid arthritis, and one with multiple sclerosis.

The ability to climb a staircase and to put on shoes and stockings is shown in

Table 5 Pain at time of follow-up examination

	Pseudarthrosis	Necrosis of femoral head	Total per cent
No pain	18	14	37
Intermittent on weight bearing	11	20	36
Intermittent spontaneous	9	8	20
Severe pain	3	4	7
Total	41	46	100

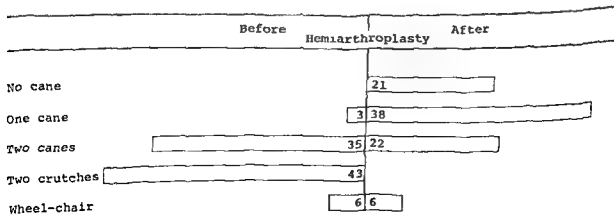


Figure 2 Mobility

Table 7 The unaided walking capacity before operation and at follow-up is shown in Figure 2. Many of those using one stick did so because of the surgeon's recommendation. All wheel-chair patients had other incapacitating diseases.

Table 6 Occupations

	No
Heavy work	5
Household work	32
Daily activities	32
Institutional care	8
Total	87

Table 7 Activities of daily living

	Yes	With some difficulty	No
Climbing stairs	45	25	13
Putting on shoes and stockings	89	19	9

DISCUSSION

The late results of hemiarthroplasty have been dealt with in many reports, but most investigations have been concerned with mixed series comprising both primary and secondary arthroplasties. The results reported here are worse than those in mixed series (*cf.* Beck 1968 and Furey et al 1961 who both report good results in 82 per cent) and still worse than the results of primary arthroplasty (Hinchey & Day 1964, Riska 1971, Tillberg 1976). The results of hemiarthroplasty for necrosis of the femoral head reported here compare well with the poor results reported in cases of coxarthrosis (Apley et al 1969, Andersson et al 1964). Osteoarthritis develops sooner or later after pseudarthrosis and especially after necrosis. After 2 years, or at about the time the lesion can be seen on x ray, 30 per cent of hips with necrosis of the femoral head have devel-

oped arthrosis (Bohler & Ender 1953). It thus seems that when a long interval has passed between the primary fracture and the arthroplasty, total arthroplasty is to be preferred, especially when necrosis of the femoral head is present. The state of acetabular cartilage should be carefully inspected at operation in every case, and if some defect is discovered a total prosthesis probably should be inserted.

Under certain circumstances hemiarthroplasty should be the primary treatment of femoral neck fractures (Lunneford 1965, Riska 1971, Tillberg 1976). Of the 105 patients in this series, 45 were over 70 years of age, and, as Barnes (1970) has reported, the rate of non-union closely parallels the severity of osteoporosis. These patients or 43 per cent of the total series, could have been spared not only the second operation but also roughly 2 years of disability often requiring hospitalization. Many debilitating illnesses also increase the rate of non-union (Johansson 1964). Of those younger than 70 years 23 patients (22 per cent) suffered from other illnesses and might have been spared a second operation (Tillberg 1976). In addition to the arthroplasty most of the patients had undergone at least two previous operations, i.e. nailing and subsequent removal of the nail. Sixty-seven per cent of the series could be classified into Pauwels' group III fractures (a fracture line at an angle of 70° or more to the horizontal). Such fractures show a high incidence of non-union (Scheck 1965). In Pauwels' group III fractures, and possibly also in group II fractures, primary hemiarthroplasty ought to be seriously considered.

In this series of secondary hemiarthroplasties the complications occurring during or immediately after operation, such as dislocation, fracture, thromboembolism, and infection are similar to those reported elsewhere (Moore 1957, Furey et al 1961, Hinchey & Day 1964), and

also to those in primary arthroplasties (Riska 1971, Tillberg 1976) The post-operative mortality is a little lower than in series dealing with primary arthroplasty (Tillberg 1976), but this might be due to the more advanced age of patients treated by primary arthroplasty

REFERENCES

- Andersson L, Hamsa W & Waring, Th (1964) Femoral head prosthesis *J Bone Jt Surg* 46 A, 1049-1068
- Apley, A G Millner, W F & Porter, D S (1969) A follow up study of Moore's arthroplasty in the treatment of osteoarthritis of the hip *J Bone Jt Surg* 51 B, 638-647
- Barnes, R (1970) Problems in the treatment of femoral neck fractures *Proc roy Soc Med* 63 1119-1120
- Barr, J S, Donovan, J F & Florens, D W (1964) Arthroplasty of the hip *J Bone Jt Surg* 46 A, 249-266
- Beck, H (1968) Technik und Ergebnisse bei 100 Hüftendoprothesen *Brun's Beitr klin Chir* 216 148-162
- Bohler, I & Guder J (1953) Hüftkopfnackrosen nach der Schenkelhalsnagelung ihre Häufigkeit und Versuche der Verhütung *Wiederherstellungschir u Traum* 1 122-130
- Furey, J G, Spencer, G F & Pierce, D J (1961) Use of hip prosthesis in femoral neck fractures *J Amer med Ass* 177 100-103
- Hierion, T, Ottosson, L G & Zachrisson B (1965) Caputnel roser och collumpeuder throsen—senresultat vid icke operativ behandling *Svenska Idk-Tidn* 111 2833 2840
- Hinchey, J J & Day, Ph L (1964) Primary prosthetic replacement in fresh femoral neck fractures *J Bone Jt Surg* 46 A, 223-240
- Johansson M H (1964) The prognosis of femoral neck fractures with special reference to complications and old age *Acta Soc Med upsalien* 69 125-160
- Lunecford, E M (1965) Use of the Moore self locking vitallium prosthesis in acute fractures of the femoral neck *J Bone Jt Surg* 47 A, 832-841
- Moore, A T (1957) The self locking metal hip prosthesis *J Bone Jt Surg* 39 A 811-827
- Pauwels, F (1935) *Der Schenkelhalsbruch Ein mechanisches Problem* F Enle Stuttgart.
- Riska, F (1971) Prosthetic replacement in the treatment of subcapital fractures of the femur *Acta orthop scand* 42 281-290
- Scheck, M (1965) Management of fractures of the femoral neck *J Bone Jt Surg* 47 A 819-829
- Tillberg B (1976) Treatment of fractures of the femoral neck by primary arthroplasty *Acta orthop scand* 47 209-213

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STRESS RADIOGRAPHICAL MEASUREMENTS OF POST-TRAUMATIC KNEE INSTABILITY

A Clinical Study

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In a prospective, consecutive clinical and stress radiographical study comprising 153 traumatic knee injuries the value of stress radiographical measurements gonylaxometry, was studied. Clinical evaluation gonylaxometry and preoperative evaluation under general anaesthesia were carried out in that order. Then the operative findings were recorded as drawings on standard diagrams. These were used as a basis for evaluation of the preoperative tests. Of all the methods evaluated, gonylaxometry was found to provide the most accurate information regarding the knee injury. Very close to this result were the findings under general anaesthesia. Anterior drawer sign was measured gonylaxometrically when damage to the anterior cruciate ligament was present, posterior drawer meant damage to the posterior cruciate ligament. Partial ruptures of cruciate ligaments did not allow antero-posterior displacements exceeding the critical levels of the test. Small positive medial instability was found with ruptures of profound medial structures, higher values with total rupture of the long superficial collateral band, and still higher values when cruciate ligament ruptures were also present. The predictive values of a positive radiographical test were 100 per cent as regards medial instability and 98 per cent for drawer looseness. The predictive values of a negative test were 96 per cent for drawer and 92 per cent for medial instability. These figures are based on the total material. 95 per cent confidence limits are given.

Key words: Knee instability, gonylaxometry, predictive values, prospective clinical evaluation, stress radiography.

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A method for stress radiographical measurement of anterior, posterior and

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medial and lateral stability in the knee joint has been described by the author (Jacobsen 1976). A series of subjects with healthy knees were used to investigate the accuracy and upper limits of the normal standard values of the

also to those in primary arthroplasties (Riska 1971, Tillberg 1976). The post-operative mortality is a little lower than in series dealing with primary arthroplasty (Tillberg 1976), but this might be due to the more advanced age of patients treated by primary arthroplasty.

REFERENCES

- Andersson, L., Hamsa W & Waring, Th (1964) Femoral head prosthesis *J Bone Jt Surg* 46 A, 1049-1068
- Apley, A G, Millner, W F & Porter, D S (1969) A follow up study of Moore's arthroplasty in the treatment of osteoarthritis of the hip *J Bone Jt Surg* 51 B, 638-647
- Barnes, R (1970) Problems in the treatment of femoral neck fractures *Proc roy Soc Med* 63 1119-1120
- Barr, J S, Donovan J F & Florens D W (1964) Arthroplasty of the hip *J Bone Jt Surg* 46 A, 249-266
- Beck, H (1968) Technik und Ergebnisse bei 100 Hüftendoprothesen *Brunns Beitr Klin Chir* 216 148-162
- Bohler, I & Ender, J (1953) Hüftkopfnekrosen nach der Schenkelhalsnagelung ihre Häufigkeit und Versuche der Verhütung *Wiederherstellungschir u Traum* 1 122-130
- Furey, J G, Spencer, G E & Pierce, D J (1961) Use of hip prosthesis in femoral neck fractures *J Amer med Ass* 177 100-103
- Hertton, T, Ottosson, L O & Zachrisson B (1965) Caputnel roser och collumspseudarthrosen—senresultat vid icke operativ behandling *Svenska Lak-Tidn* 62 2833-2840
- Hinchey, J J & Day, Ph L (1964) Primary prosthetic replacement in fresh femoral neck fractures *J Bone Jt Surg* 46 A 223-240
- Johansson, S H (1964) The prognosis of femoral neck fractures with special reference to complications and old age *Acta Soc Med upsalien* 69, 125-160
- Lunceford, F M (1965) Use of the Moore self locking vitallium prosthesis in acute fractures of the femoral neck *J Bone Jt Surg* 47 A, 832-841
- Moore, A T (1957) The self locking metal hip prosthesis *J Bone Jt Surg* 39 A 811-827
- Pauwels, F (1935) *Der Schenkelhalsbruch Ein mechanisches Problem* F Enke Stuttgart.
- Riska, F (1971) Prosthetic replacement in the treatment of subcapital fractures of the femur *Acta orthop scand* 42 231 290
- Scheck, M (1965) Management of fractures of the femoral neck *J Bone Jt Surg* 47 A 819-829
- Tillberg, B (1976) Treatment of fractures of the femoral neck by primary arthroplasty *Acta orthop scand* 47, 209-213

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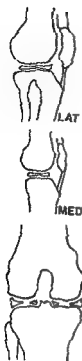


Figure 1 Diagram for routine drawings of ligament and capsule ruptures found at operation

at 90° of knee flexion with the foot fixed point leg anteriorly (starting from 'neutral position 0°') a force of 30 kg being applied (Measurement of rotation will be dealt with in a following publication) Medial and lateral instability as well as anterior and posterior displacements were measured on the radiographs and recorded before operation.

Preoperative clinical evaluation was carried out on admission (before gonylaxometry) in 122 of the cases by another senior surgeon (chief or senior registrar) and the results were sealed in 31 cases the clinical evaluation was performed by the author and became the first entry in the patients' record. Preoperative evaluation under general anaesthesia was carried out, after gonylaxometry in all cases by the author. Operative findings were recorded in detail and drawings were made of the findings on standard diagrams.

Figure 1)

The clinical evaluation was simplified to include only a description of whether or not instability was present. If an attempt was made to use three degrees: 1) no instability, 2) a little instability, 3) gross instability, the clinical evaluation became very uncertain.

The stress radiographical findings were corre-

lated with the operative findings. The preoperative clinical findings and the preoperative findings under anaesthesia were also correlated with the findings at operation. As expressions of these correlations, the predictive value of a positive test, PV_{pos} , and the predictive value of a negative test, PV_{neg} , are used, as described by Vecchio (1966) and in Scandinavia by Wulff (1976). The PV_{pos} is defined as the probability of a certain ligament injury if the test is positive. The PV_{neg} is defined as the probability of non injury if the test is negative.

FINDINGS

Group 1

The stress radiographical measurements of group 1 can be seen in Figure 2. Instabilities were measured on the radiographs in millimetres with one decimal and are shown and defined throughout this paper as the differences between the patient's injured and healthy knee. In accordance with the earlier measurements on healthy subjects, 20 mm is used as the upper normal limit (critical level) for medial and lateral instability and 30 mm as the critical level for abnormal anterior or posterior displacement.

Patients nos 1 to 11 showed, at stress radiography, no collateral looseness at all, and the measurements were true negative as the operations showed no injuries to the collateral ligaments, but revealed other injuries (of the meniscus or dislocations of the knee cap). Patients nos 1, 2 and 3 had small tears of isolated fibres anteriorly in the superficial medial collateral ligament, this nevertheless being intact in more than two-thirds of its breadth, thus not allowing any looseness in the frontal plane. Nos 12 to 57 represent isolated injuries to the medial collateral ligaments. At gonylaxometry they all showed true positive values as they exceeded the critical level of 2 mm and true negative values for anterior-posterior displacement (<3 mm). Among these, nos 12 to 24 had the smallest

parameters mentioned. A logical next step is an investigation of the clinical value on a clinical material. A prospective study is presented below comprising preoperative stress-radiographical measurements compared with 1) operative findings, 2) a preoperative clinical evaluation and 3) a preoperative evaluation under general anaesthesia.

PATIENTS

The material comprises a prospective consecutive series of 151 patients with 153 traumatic knee injuries. Two patients have been examined and operated upon twice (in the same knee). The investigation took place from January 1974 to November 1975. The age and sex distribution is shown in Table 1, the precipitating activity or cause of the injury is shown in Table 2. There are a great number of young people in the age group 17 to 30 years as the material comprises largely sports injuries. The preponderance of men is explained by the great number of soccer injuries.

All the patients were referred with a suspicion of ligamentous injury to the knee and all were examined and operated upon. They were divided into three groups on the basis of the duration of time from trauma to operation.

Group 1 duration 14 days or less (recent injuries)

Group 2 duration from 15 days to 3 months

Group 3 duration exceeding 3 months

The group of recent injuries comprised 90 knee joints. Local anaesthesia (Lidocaine chloridum) was necessary during the measurements. It was combined with noradrenaline for the collateral ligaments and the capsule but used alone intra-articularly (5 ml 1% per cent, after aspiration of hyarthrosis or haemarthrosis). In

Table 2 Precipitating activity or cause of the injury

Precipitating cause	Total	Men	Women
Soccer	79	76	3
Handball	11	6	5
Other ball games (basketball volleyball badminton)	8	4	1
Skating	17	7	10
Other sports	11	10	1
All sports total	124	103	21
Work, traffic and holiday accidents	29	22	7
Total	153	125	28

recent injuries observation of the damage to ligaments and capsular structures is facilitated by the absence of scar tissue. On the other hand pain may be violent and so in three of the 99 injuries measurement of anteroposterior instability could not be carried out.

Group 2 comprised only 26 knee injuries. The use of local anaesthesia was also necessary during stress radiography in this group. During operation the patho-anatomy of the injuries was blurred by scar tissue and atrophy of the cruciate ligaments.

Group 3 comprised 37 knees. Here no pain interfered with the measurements and local anaesthesia was not utilized. The original patho-anatomy of the injuries to collateral ligaments and capsule was totally blurred by scar tissue and injuries to the cruciate ligaments could be graded only as partial or total atrophy. Per operative judgement of any healing with elongation of injured cruciate ligaments is very difficult and uncertain and has been avoided.

Table 1 Age and sex of the 153 patients

Age in years	Total	Men	Women
13-20	39	35	4
21-30	69	58	11
31-40	27	23	4
41-50	13	7	6
51-60	3	1	2
61-67	2	1	1
13-67	153	125	28 (18.3%)

METHOD

The preoperative stress radiographical measurements were carried out as described previously (Jacobsen 1976) viz medial and lateral instability was measured on a-p radiographs with the patient's knees flexed 20° (neutral position 160°) with a 9 kg stress (abduction or adduction) on both knees at the same time. Only the gap in the frontal plane was measured, this being used as a definition of medial and lateral instability. The foot and femur were fixed to avoid rotation. The drawer signs were measured

Table 3 Predictive values in knee injuries ≤ 14 days Medial instability

Gonylaxometry $TN = 11$ $FN = 5$ $TP = 63$ $FP = 0$ $N = 89$

$$\text{Predictive value of pos test} = P\bar{V}_{\text{pos}} = \frac{TP}{TP + FP} = \frac{63}{63 + 0} = 100\% \\ (95\% \text{ confidence limits } 94-100\%)$$

$$\text{Predictive value of neg test} = P\bar{V}_{\text{neg}} = \frac{TN}{TN + FN} = \frac{11}{11 + 5} = 68\% \\ (95\% \text{ confidence limits } 61-93\%)$$

Manual test $TN = 10$ $FN = 2$ $TP = 66$ $FP = 12$ $N = 90$

$$P\bar{V}_{\text{pos}} = \frac{TP}{TP + FP} = \frac{66}{66 + 12} = 85\% (75-92\%)$$

$$P\bar{V}_{\text{neg}} = \frac{TN}{TN + FN} = \frac{10}{10 + 2} = 83\% (52-98\%)$$

Test under general anaesthesia $TN = 20$ $FN = 3$ $TP = 65$ $FP = 2$ $N = 90$

$$P\bar{V}_{\text{pos}} = \frac{TP}{TP + FP} = \frac{65}{65 + 2} = 97\% (90-100\%)$$

$$P\bar{V}_{\text{neg}} = \frac{TN}{TN + FN} = \frac{20}{20 + 3} = 87\% (66-97\%)$$

TN = true negative TP = true positive FN = false negative FP = false positive N = number of patients tested

amount of positive medial instability nearly all of them less than 4 mm and the operative findings revealed ruptures of the deep medial collateral and oblique posteromedial ligaments, sometimes together with smaller tears in the superficial medial collateral ligament but never a total rupture of this structure. On the contrary patients nos 25 to 37 all (except one) showed greater medial instability (> 4 mm) and they all had a total rupture of the superficial medial collateral ligament which Warren et al (1974) have called "the prime static stabilizer of the medial side of the knee. Moreover it can be seen that gross medial and lateral instabilities are found in combination with gross drawer signs (to the right in the diagram Figure 2).

The main purpose of the development of the gonylaxometer has not been for diagnostic use in acute injuries but for

scientific use (follow up investigations and investigations of old painless unstable knee joints). However, an evaluation of the method for acute cases ought to be made and so the predictive values, $P\bar{V}_{\text{pos}}$ and $P\bar{V}_{\text{neg}}$ were calculated (Table 3).

Lateral instability In two cases (nos 58 and 59) with operatively proven small incomplete ruptures of the lateral collateral ligament there was no instability. The four other cases had grave injuries and positive measurements (Figure 2).

Drawer symptoms in group 1 Anterior drawer range at gonylaxometry was up to 16 mm (difference from the healthy knee) and posterior drawer up to 21 mm. The amount of anterior and posterior displacement was evenly spread from the critical levels to the top of the rank. Cruciate ligament injuries were found in nos 60 to 90. Three cases with injuries to both cruciate ligaments were measured

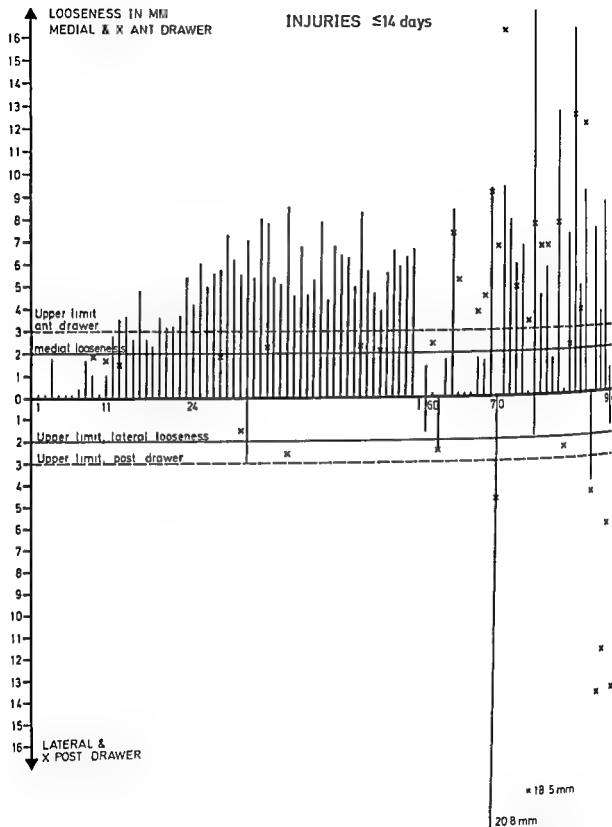


Figure 2 Diagram showing stress radiographically measured instabilities in group 1 Differences between the patients injured and healthy knee Medial collateral instability: columns above the axis of the abscissa Lateral instability: columns below the axis Anterior displacement or drawer as an x above the axis and posterior drawer as an x below the axis (values below the axis are thus also positive) Every column and cross show measurements on one patient, the patient number being the abscissa

Table 3 Predictive values in knee injuries ≤ 14 days Medial instabilityGonylaxometry $TN = 21$, $FN = 5$, $TP = 63$, $FP = 0$, $N = 89$

$$\text{Predictive value of pos test} = PV_{\text{pos}} = \frac{TP}{TP + FP} = \frac{63}{63 + 0} = 100\% \\ (95\% \text{ confidence limits } 94-100\%)$$

$$\text{Predictive value of neg test} = PV_{\text{neg}} = \frac{TN}{TN + FN} = \frac{21}{21 + 5} = 81\% \\ (95\% \text{ confidence limits } 61-93\%)$$

Clinical test $TN = 10$, $FN = 2$, $TP = 66$, $FP = 12$, $N = 90$

$$PV_{\text{pos}} = \frac{TP}{TP + FP} = \frac{66}{66 + 12} = 85\% (75-92\%)$$

$$PV_{\text{neg}} = \frac{TN}{TN + FN} = \frac{10}{10 + 2} = 83\% (52-98\%)$$

Test under general anaesthesia $TN = 20$, $FN = 3$, $TP = 65$, $FP = 1$, $N = 90$

$$PV_{\text{pos}} = \frac{TP}{TP + FP} = \frac{65}{65 + 1} = 97\% (90-100\%)$$

$$PV_{\text{neg}} = \frac{TN}{TN + FN} = \frac{20}{20 + 3} = 87\% (66-97\%)$$

TN = true negative TP = true positive FN = false negative, FP = false positive N = number of patients tested

amount of positive medial instability, nearly all of them less than 4 mm, and the operative findings revealed ruptures of the deep medial structures, i.e., the profound medial collateral and oblique posteromedial ligaments, sometimes together with smaller tears in the superficial medial collateral ligament but never a total rupture of this structure. On the contrary, patients nos 25 to 57 all (except one) showed greater medial instability (> 4 mm) and they all had a total rupture of the superficial medial collateral ligament, which Warren et al (1974) have called "the prime static stabilizer of the medial side of the knee". Moreover it can be seen that gross medial and lateral instabilities are found in combination with gross drawer signs (to the right in the diagram, Figure 2).

The main purpose of the development of the gonylaxometer has not been for diagnostic use in acute injuries but for

scientific use (follow-up investigations and investigations of old painless unstable knee joints). However, an evaluation of the method for acute cases ought to be made and so the predictive values, PV_{pos} and PV_{neg} , were calculated (Table 3).

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Two showed a marked drawer sign both anteriorly and posteriorly, while one was negative (see below). Injuries to the posterior cruciate ligament without injury to the anterior were found in five patients, all with true positive measurements of posterior drawer. Anterior drawer could not be measured radiographically in seven cases of partial rupture and in one case of intrasynovial rupture of the anterior cruciate ligament while partial rupture of the anterior cruciate ligament was demonstrated by small values in two cases.

Table 4 Predictive values Total a-p displacement (drawer/no drawer) Injuries ≤ 14 days
95 % confidence limits in brackets

Goniyaxometry

N = 87, FP = 0, TP = 21, FN = 10, TN = 56

PV_{pos} = 100 % (84-100 %)

PV_{neg} = 85 % (74-92 %)

Clinical test

N = 90, FP = 7, TP = 18, FN = 14, TN = 51

PV_{pos} = 72 % (51-88 %)

PV_{neg} = 78 % (67-88 %)

Test under general anaesthesia

N = 90, FP = 2, TP = 21, FN = 11, TN = 56

PV_{pos} = 91 % (72-99 %)

PV_{neg} = 81 % (73-92 %)

Two cases with total rupture (one of the anterior and one of the anterior plus posterior cruciate) did not show any drawer sign either at goniyaxometry or during examination under general anaesthesia. During operation the femoral condyle was found to be locked in a great bucket-handle-lesion of the meniscus. In the calculation of predictive values these 10 cases (including partial ruptures) are considered as false negative.

Table 4 gives the values for the patients with total a-p displacement exceeding critical levels. If anterior and posterior drawer are separated, the clinical test becomes more inaccurate while goniyaxometry and evaluation under

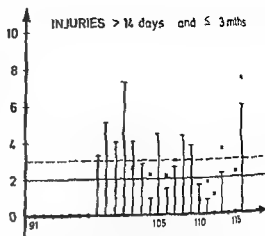


Figure 3 Stress radiographically measured instabilities in group 2. Medial instability: column above the axis. Anterior drawer: \pm above the axis. No lateral or posterior cruciate injuries: this group.

general anaesthesia remains unchanged. Table 4 shows the superiority of goniyaxometry also in the acute diagnostic field but this is indeed very moderate compared with examination under general anaesthesia.

Group 2 (26 knee joints)

The stress radiographical measurements are shown in Figure 3. There were no cases of lateral collateral or posterior cruciate ligament injury. There were no cases of false negative or false positive medial instability, which ranged up to 7.3 mm. Four cases of peroperatively verified partial anterior cruciate ligament ruptures could not be demonstrated by goniyaxometry or by examination under general anaesthesia. Two out of three total ruptures of the anterior cruciate ligament showed measurements of anterior drawer exceeding the critical level and they were also estimated as positive during clinical examination and examination under general anaesthesia. The third case had a negative drawer sign at goniyaxometry as well as during clinical examination and the examination under anaesthesia. This group by itself too small for statistical analysis.

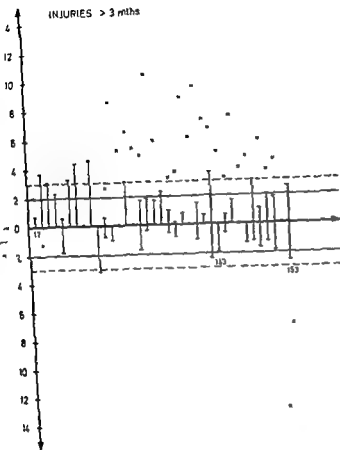


Figure 4 Stress radiographically measured instabilities in group 3 For explanation of indications refer to Figure 2

Group 3 (37 knees)

There was no pain during stress radiography and local anaesthesia was not used. The measurements can thus be considered to be accurate. One bucket handle lesion with locking of the femoral condyle and false negative measurement of drawer was found. Figure 4 shows the findings at gonylaxometry. Most remarkable is the medial instability which is slight in these chronic injuries (range up to 4.6 mm). In 22 cases no collateral instability at all was found either at gonylaxometry or at operation.

One false positive anterior drawer sign (5 mm) was found. The patient had a marked quadriceps atrophy following

arthrotomy and suture of the medial collateral ligament 2 years earlier, after a work accident. He had recurrent hyarthrosis, pain in the knee and a feeling of instability. The present operation showed normal structure of the cruciate ligaments, but they were loose.

The drawer signs in this group ranged from 3.3 to 15.1 mm, mean 6.6 mm. The $PV_{pos} = 96$ per cent (80–100 per cent) and $PV_{neg} = 92$ per cent (67–100 per cent) are approximately the same as in group 1.

Finally an evaluation of the total material was made. As it is normally impossible to detect partial cruciate ligament rupture by this method, as pointed

Two showed a marked drawer sign both anteriorly and posteriorly, while one was negative (see below). Injuries to the posterior cruciate ligament without injury to the anterior were found in five patients, all with true positive measurements of posterior drawer. Anterior drawer could not be measured radiographically in seven cases of partial rupture and in one case of intrasynovial rupture of the anterior cruciate ligament while partial rupture of the anterior cruciate ligament was demonstrated by small values in two cases.

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PV_{pos} = 100 % (84-100 %)

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Clinical test

N = 90, FP = 7, TP = 18, FN = 14 TN = 51

PV_{pos} = 72 % (51-88 %)

PV_{neg} = 78 % (67-88 %)

Test under general anaesthesia

N = 90 FP = 2, TP = 21 FN = 11 TN = 56

PV_{pos} = 91 % (72-99 %)

PV_{neg} = 84 % (73-92 %)

Two cases with total rupture (one of the anterior and one of the anterior plus posterior cruciate) did not show any drawer sign either at goniyaxometry or during examination under general anaesthesia. During operation the femoral condyle was found to be locked in a great bucket-handle lesion of the meniscus. In the calculation of predictive values these 10 cases (including partial ruptures) are considered as false negative.

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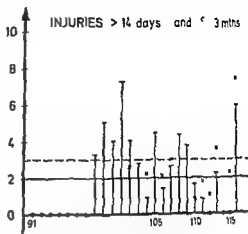


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ligament as positive drawer signs exceed the critical levels used here. There may be an anatomical reason for this. The anterior cruciate ligament consists of a posterolateral part, which is taut at knee extension and more slack at 90° knee flexion, and an anteromedial part which is taut at 90° knee flexion. This fact has been described in anatomical text books (Tiek 1904; Jang & Wachsmuth 1972). It was not mentioned by Kennedy et al. in their biomechanical work (1974) but has been advanced again by Furman et al. (1976). In eight of the cases where measurement of partial anterior cruciate rupture was not possible, a rupture of the posterolateral fibres was found leaving the anteromedial fibre bundle which is taut in the position of drawer measurement in the gonylaxometer intact. In this situation it is impossible to bring about any anterior drawer sign and these cases ought not to be designated false negative (neither do they offer an indication for operation—see below). Table 4 which counts these ruptures as false negatives thus represents an absolute minimum of the PV_{neg} at stress radiography.

Posterior drawer signs were only found coincident with ruptures of the posterior cruciate ligament and anterior drawer signs coincident with ruptures of the anterior cruciate ligament in agreement with the works of Palmer (1938) and numerous others, most recently Furman et al. (1976). Group 1 also comprises four isolated anterior drawer signs (true positive) with true negative medial instability. They represent three total ruptures and one partial and in agreement with Wang et al. (1970) contribute to the continuous controversy of whether an isolated injury of the anterior cruciate ligament may occur. It does.

Thus gonylaxometry in this clinical material shows patterns of instability in agreement with findings of other authors, also those who have been working experi-

mentally using fresh human knee specimens. Moreover when used as a diagnostic test gonylaxometry must be evaluated in relation to its primary function: assessment for operation. Those patients in group 1 whose measurements of drawer looseness were false negative ought not to have been operated upon in 8 out of 10 cases as their cruciate ligament ruptures were partial or intra-synovial. With this background the PV_{neg} could be calculated to 97 per cent (and PV_{pos} 100 per cent). A similar consideration can be made for four out of five false negative measurements on fresh medial collateral ruptures where total rupture of the superficial band was not found. Being also a diagnostic aid in acute and other knee injuries gonylaxometry is therefore evaluated as a method of high accuracy.

REFERENCES

- Fick R (1904) *Handbuch der Anatomie und Mechanik der Gelenke* III. In: *Handbuch der Anatomie des Menschen* Ed von Bardeleben K. Band II Teil III p 546. Gustav Fischer, Jena.
- Furman W, Marshall J L & Gurgis F C (1976) The anterior cruciate ligament: a functional analysis based on postmortem studies. *J Bone Jt Surg* 58-A 179-185.
- Hallén L C & Lindahl M (1965) The lateral stability of the knee joint. *Acta orthop scand* 36 179-191.
- Jakobsen K (1977) Stress radiographical measurement of the anteroposterior, medial and lateral stability of the knee joint. *Acta orthop scand* 47 335-344.
- Jonasch F (1958) Zerreissung des äusseren und inneren Kniegelenkbandes. *Wachr Unfallheilk Beihft* 59 1-83.
- Kennedy J C, Weinberg H W & Wilson A S (1974) The anatomy and function of the anterior cruciate ligament. *J Bone Jt Surg* 56-A 223-235.
- Jang J & Wachsmuth W (1972) *Praktische Anatomie* Band I Teil IV *Bein und Statik* p 212-257. Springer Verlag, Berlin.
- Palmer I (1938) On the injuries to the ligaments of the knee joint. A clinical study. *Acta chir scand* LXXXI Suppl III p 282.

out above, the negative measurements of these injuries are counted as true negative. For total anteroposterior displacements $PV_{pos} = 98$ per cent (89–100 per cent), $PV_{neg} = 96$ per cent (90–99 per cent), for medial instability $PV_{pos} = 100$ per cent (96–100 per cent) and $PV_{neg} = 92$ per cent (83–97 per cent).

DISCUSSION

The main purpose of this report was to show how collateral and anteroposterior instabilities in patients could be measured with relative accuracy by goniometry. It was also important to discover if certain injuries to the ligaments showed certain patterns of instability at stress radiography.

The pattern of medial ligament injuries is shown by stress radiography to agree with that found by Warren et al (1974). These authors investigated the medial structures in fresh human knee specimens. They have shown that the anterior long fibres of the superficial medial collateral ligament for a breadth of approximately 10 mm are the main stabilizing factors of the medial side of the knee. As mentioned above medial instabilities more than approximately 4 mm at stress radiography cannot be demonstrated unless this part of the ligament has been totally ruptured and if this is the case the instability is > 4 mm. Warren et al (Chart II) found an increase in instability of 8 mm (mean) in this situation—with intact cruciate ligaments—which matches well with the findings in patients nos 25–57 on Figure 2.

Positive findings from 2 to 4 mm indicate ruptures in the deep medial ligaments without total rupture of the superficial ligament (nos 12–24). In agreement with Hüllén & Lindahl (1965) the very large medial and lateral instabilities are found in ruptures of both cruciate

ligaments and the posterior joint capsule in connection with total rupture of the medial or lateral structures (nos 70 and 76).

The most remarkable finding in the group of chronic injuries is that colateral instability is only slight, in 22 cases there was none at all. This is a fact for both patients with and patients without rupture of cruciate ligaments. This finding indicates that the medial colateral ligament and the capsular structures are capable of spontaneous restitution after trauma even if untreated or treated only by a plaster cast, as found by Jonasch (1958). He measured, at follow-up, the medial instability in the frontal plane using a simple radiographical technique and manual pressure (2000 plaster cast-treated patients). But it must be stressed that this fact tells nothing about rotatory instability and the role of a possible coincident a-p instability.

In the total material three cases of negative a-p measurements were found in which the subsequent arthroscopy showed a "locking" of the femoral condyle to the tibial by a bucket handle lesion of the meniscus. These are all considered as false negative in the statistical calculations. This is justified from a diagnostic point of view but hardly from the point of view of the measuring technique.

The investigation reveals an even distribution of the measured values of all parameters on the scale from the critical levels and upwards. This also applies to the a-p displacements there being no "free interval" between the upper normal values (97.5 per cent border) and the pathological values. This is to be expected in a biological material with very complex injuries to different ligaments in the joint—the degree of a driver sign also being dependent on the condition of the other ligaments and the capsule.

Generally it is not possible to measure partial ruptures of the anterior cruciate

BELOW-KNEE AMPUTATION FOR ISCHAEMIC GANGRENE

Prospective, Randomized Comparison of a Transverse and a Sagittal Operative Technique

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In a prospective randomized study a comparison was made of the results of primary below knee amputation for ischaemic gangrene carried out by two methods. In 47 cases by the transverse technique with a long posterior musculo cutaneous flap and in 41 cases by the sagittal technique using equally large medial and lateral musculo-cutaneous flaps—in both instances followed by 2 weeks in a half-open plaster cast with extended knee. The sex ratio and age distribution were the same in both groups. Minor differences in the vascular condition between the groups, assessed by the duration of rest pain, pulsation findings, extent of gangrene, and frequency of diabetes, wholly or partially equalized each other. The course of healing was the same in both groups, primary healing being attained in 38 per cent and 41 per cent, respectively ($0.70 < P < 0.80$). There was also no difference between the results as regards limb fitting, ambulation, occupational or social status. It is concluded that the choice between the two methods can be based merely upon surgical skill and the ischaemic changes in the lower leg.

Key words: amputation, amputation stumps, gangrene, below knee amputation.

Accepted 28 ix 76

Increased longevity has entailed an increased number of lower-extremity amputations for vascular diseases (Hansson 1964). Rehabilitation is greatly facilitated by preserving the knee (Sarmiento et al 1970). Recent advances, involving an increased frequency of below-knee as compared with above-knee amputation in ischaemic gangrene, have been obtained with improved pre- and post-operative management (plaster casts, improved and non-traumatic surgical technique, and new surgical methods).

A sagittal technique for below-knee amputations was described by Tricy

(1966) and a similar technique by Persson & Sundén (1971). A few years later, Persson (1974) demonstrated the superiority of this technique over the conventional technique of using anterior and posterior flaps.

The present prospective, randomized study was designed to compare the results of below knee amputation performed by the transverse technique using a long posterior musculo-cutaneous flap (Bickel 1943, Perry 1963, Romano & Bruggess 1971) with the results of Persson & Sundén's sagittal technique.

- Wang J B, Rubin, R M & Marshall, J I (1975) A mechanism of isolated anterior cruciate ligament rupture *J Bone Jt Surg* 57 A, 411-413
- Warren L F, Marshall, J I & Gurgis, F (1974) The prime static stabilizer of the medial side of the knee *J Bone Jt Surg* 56-A 665-674 (Chart II)
- Vecchio T J (1966) Predictive value of a single diagnostic test in unselected populations. *New Engl J Med* 274 1171-1173
- Wulff, H R (1976) *Rational diagnosis and treatment* pp 182 Blackwell Oxford.

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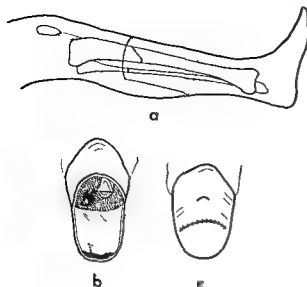


Figure 1 Transverse technique a Skin incision b Posterior flap c Skin closure

MATERIAL AND METHODS

The material comprises all lower extremity amputations done for ischaemic gangrene in the Department of Orthopaedic Surgery, O. Odense Hospital during the period June 1972 through December 1974 (Table 1). Primary below knee amputation was performed to the widest possible extent if the cutaneous blood supply was deemed sufficient. The primary amputation level was distributed as shown in Table 2.

Table 1 Total number of lower limb amputations for ischaemic gangrene

Diagnosis	No of patients	No of extremities
Arteriosclerosis	59	66
Diabetes	37	45
Mixed a/v insufficiency	1	1
Embolism/thrombosis	4	4
Total	101	116

Table 2 Primary level of amputation for ischaemic gangrene

	No of extremities	Percentage
Foot and toes	5	4
Below knee	88	76
Above knee	23	20
Total	116	100

Primary below knee amputation for ischaemic gangrene was performed on 88 extremities which form the basis of this study.

The primary below knee amputation was done by the sagittal technique on all patients whose year of birth was an even number and by the transverse technique on all whose year of birth was an odd number. The transverse amputation (Figure 1) utilized one long posterior musculocutaneous flap and no anterior flap in the sagittal amputation (Figure 2) equally large medial and lateral musculocutaneous flaps were used. In both techniques the tibia was cut obliquely and covered with muscle using chromic catgut sutures in the fascia. The skin was closed by atraumatic 3/0 nylon sutures. As little injury as possible was inflicted on the tissue—in particular the skin—for instance by not applying forceps. A half open plaster cast was applied with extended knee. Suction drainage was used after transverse amputation and during the latter year of the study period also after sagittal amputation. The patients were allowed to sit up on the day after the operation but further mobilization was not allowed until the plaster was removed 2 weeks later. Antibiotics were not routinely used.

Table 3 gives the distribution of the two operative techniques, the sex ratio, the mean age and frequency of diabetes in the two groups. The age distribution is shown in Figure 3. Table 4 further demonstrates the comparability of the two groups. The transverse amputees had a somewhat longer duration of rest pain than the sagittal amputees. The sagittal group had somewhat more favourable pulsatory findings than the transverse group 27 per cent

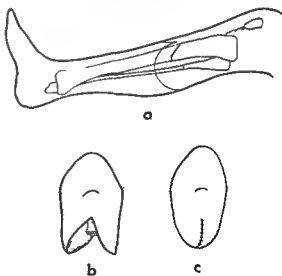


Figure 2 Sagittal technique a Skin incision b Sagittal flap c skin closure

Table 3 Primary below-knee amputation for ischaemic gangrene

Technique	No of extremities	Men	Women	Mean age (years)	Diabetes
Sagittal (medial and lateral flaps)	41	24	17	70.0	16 (39%)
Transverse (long posterior flap)	47	22	25	70.5	22 (47%)

and 13 per cent respectively, having pulsation in the popliteal artery or distal to it. Of the sagittal amputees 34 per cent had gangrene in the ankle region or proximal to it as compared with 46 per cent of the transverse amputees. Forty six per cent of the sagittal and 34 per cent of the transverse cases were assessed by a vascular surgeon, 22 and 13 per cent respectively had vascular surgery. Lastly ambulation or occupational and social status were approximately the same in both groups.

Table 4 Duration of rest pain, extent of gangrene and lowest palpable pulse in patients treated for ischaemic gangrene by primary below knee amputation. The figures in brackets give the absolute number of amputations within each group.

	Duration of rest pain	
	Sagittal	Transverse
No pain	(41) 10%	(47) 13%
1 month	(4) 15%	(6) 15%
1-3 months	(6) 46%	(7) 33%
3 months	(19) 29%	(11) 49%
	(12)	(23)

	Extent of gangrene	
	Sagittal	Transverse
Toe and forefoot	(41) 66%	(47) 54%
Ankle	(27) 22%	(25) 34%
Above ankle	(9) 18%	(18) 44%
Mid leg	(5) 8%	(2) 4%
	(10)	(2)

	Lowest palpable pulse	
	Sagittal	Transverse
Pedal	(41) 5%	(47) 4%
Popliteal	(2) 22%	(2) 9%
Femoral	(9) 63%	(4) 74%
Aorta	(26) 10%	(35) 13%
	(4)	(6)

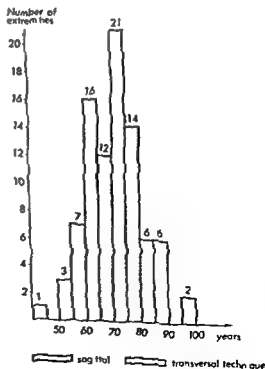


Figure 3 Age distribution of 88 patients treated by primary below-knee amputation.

Table 5 Results of primary below knee amputation for ischaemic gangrene

Technique	No of extremities	Healing after primary below-knee amputation		Healing after re-amputation		Died before healing		Not healed at follow up	
		primary	secondary	above-knee	below-knee	above-knee	below-knee	above-knee	below-knee
Sagittal	41	17* (41 %)	7 (17 %)	10	1	4	1	0	1
Transverse	47	18* (38 %)	10 (21 %)	7	4	2	3	1	1

* $0.70 < P < 0.80$ (χ^2 test)

RESULTS

All surviving patients were seen at follow-up an average of 11.7 months, range 3.5-22 months, after the amputation. Twenty had died before the follow-up examination, but the course of wound healing is known for all. There was no difference in primary or secondary healing between the two groups (Table 5).

The re-amputation rate was a poor criterion of the value of the two operative methods, as in some of the cases healing was not obtained after re-amputation.

In all, healing at the primary amputation level was attained during the study period by 61 per cent (25/41) of the sagittal amputees and by 68 per cent (32/47) of the transverse amputees, which is 65 per cent of all primary below-knee amputees, but in five of the cases healing was not obtained until re-amputation had been performed. The difference between the two groups is not significant ($0.40 < P < 0.50$, χ^2 test). The result was better in diabetics, who exhibited healing at the primary level in 82 per cent, than in the non-diabetics who healed in 48 per cent at the primary level ($0.001 < P < 0.005$).

When considering the total material of extremities with ischaemic gangrene, the definitive frequency of below-knee amputation was 55 per cent (64/116),

above-knee amputation 41 per cent (47/116), and partial foot or toe amputation 4 per cent (5/116).

The mortality within the first 3 months after the amputation was 17 per cent (8/47) among the transverse amputees as against 10 per cent (4/41) among the sagittal amputees. However there was a corresponding imbalance in the frequency of heart disease, viz. 57 per cent and 27 per cent in the two groups.

Limb fitting was successful in 78 per cent of the sagittal and in 72 per cent of the transverse amputees. Sixty-one per cent of both groups were fitted with below-knee prostheses, but the PTB prosthesis could be used by a larger number of the transverse amputees (26/47 = 55 per cent) than of the sagittal ones (18/41 = 44 per cent) who were a little more apt to have stump complaints, especially in the form of pressure due to the situation of the scar distally over the tibial stump.

Ambulation, occupational and social status were uniformly impaired in both groups as compared with the pre-amputation condition. At follow-up, 65 per cent (57/88) of all the primary below-knee amputees were able to walk on their artificial limb, without assistance by another person. Thirteen per cent (11/88) were institutionalized, while 61 per cent (56/88) were living at home.

DISCUSSION

Several authors have demonstrated that below knee amputation can be successfully accomplished in more patients with ischaemic gangrene of the lower extremities than previously assumed. For instance Sarmiento et al (1970) comparing two 4 year periods found a significant decrease in the number of re amputations from below knee to above knee level while simultaneously there had been an appreciable increase in the frequency of primary below knee amputations. The improvement in the results coincided with the introduction of immediate post surgical prosthetic fitting. A similar advance was found by Persson (1974) when changing from the conventional technique of equally long anterior and posterior flaps to the sagittal below knee amputation technique and theoretical advantages of the new method were given part of the credit. However both studies were retrospective and the methods compared were not used concurrently during the study period. Therefore it cannot be ruled out that other factors may have been decisive.

The present study was designed as a prospective randomized investigation. The assessment of the results depends upon the comparability of the two groups treated. The duration of rest pain, pulsation findings and the extent of the gangrene afford an impression of a more favourable vascular state among the sagittal than among the transverse amputees. In return it might be expected that the influence of this imbalance upon the therapeutic results would be wholly or partially obliterated by the unequal distribution of diabetes in the two groups (Table 3) since like Persson (1974) we found essentially better therapeutic results in diabetes than in non-diabetics and since moreover the pulsation findings were the same in both groups of diabetics. The latter is important seeing

that according to Moore et al (1972) diabetics can be considered better candidates for below knee amputation than non diabetics only if they do not have occlusion of major vessels.

Conclusion

There was no difference in the results of below knee amputation for ischaemic gangrene carried out by the transverse technique with a long posterior flap and by the the sagittal technique with two equally large medial and lateral musculocutaneous flaps. The choice between the two methods can be based merely upon surgical skill or upon the ischaemic changes on the lower leg.

The increased use of primary below knee amputation for ischaemic gangrene in the elderly entails great advantages during convalescence if it is possible to preserve the knee. But the price of this advantage is paid for by the group of patients who later must submit to above knee amputation—in our series 24 out of 88 patients (27 per cent). Therefore there is still a need for a method of pre operative assessment of the chances of healing and thereby a guidance in the choice of amputation level (Schousbo & Zdravkovic 1974).

REFERENCES

- Bychel W H (1943) Amputations below the knee in occlusive arterial diseases. *Surg Clin Amer* 23 932-934.
- Hansson J (1964) The leg amputee. *Acta orthop scand* Suppl 69.
- Moore W S, Hall J D & Ilm J C (1972) Below the knee amputation for ischaemic gangrene. *Amer J Surg* 124 127-134.
- Perry Th Jr (1963) Below knee amputation. *Arch Surg* 86 199-209.
- Persson H M (1974) Sagittal incision for below knee amputation in ischaemic gangrene. *J Bone Jt Surg* 56 B 110-114.
- Persson B M & Sundén G (1971) Amputation på underbenet vid kändersgangran. *Nord Med* 86 1013-1019.

- Romano R I & Burgess I M (1971) Level selection in lower extremity amputations *Clin Orthop* 74 177-184
- Sarmiento A May Bella J Sinclair, W F McCollough N V & Williams F M (1970) Lower extremity amputation The impact of immediate postsurgical prosthetic fitting *Clin Orthop* 68 22-31
- Schousbo O & Zdravkovic B (1974) Cutaneous blood flow in lower extremity gangrene measured with ^{133}Xe on *Proceedings of the Combined Meeting of the Danish and Dutch Orthopaedic Associations* Nijmegen The Netherlands Sept 1971 11 Berman A R M et al p 127-131
- Tracy G D (1966) Below level amputation for ischaemic gangrene *Pacific Med Surg* 74 251-253

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FRACTURE OF THE BODY OF THE TALUS

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Fifty one patients with fracture of the body of the talus were seen at follow up examination an average of 23 months after treatment. Osteonecrosis had developed in 3 out of 17 patients with displaced shearing or crush fractures of the trochlea. Malunion as well as subluxation predisposed to osteoarthritis in the subtalar and talocrural joints. Thus osteoarthritis was present in 9 out of 21 patients without malunion in 8 out of 16 patients with malunion, and in 11 out of 14 with malunion as well as subluxation. Judging from the nature of the complaints the difficulties in rehabilitation and the disability assessment the prognosis was fairly grave, also after the small, usually non displaced fractures of the posterior and lateral tubercles. Out of 20 patients with fractures of this type only 6 obtained almost complete relief from their symptoms; only 8 could go back to their previous work on a full time basis and 11 were assessed to be 10 per cent or more disabled. Fractures in the posterior and lateral tubercles must therefore be interpreted as links in more extensive injuries involving the subtalar joint and possibly the talocrural joint with associated injuries to articular cartilage, joint capsules and ligaments.

Key words: talus fracture, osteoarthritis, osteonecrosis, avascular necrosis.

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The body of the talus is subjected to tremendous strain during walking and running, in connection with the acceleration and deceleration of the body mass (Weber 1966). Only certain non physiological forces — e.g. pronounced caudal compression, during pronation and especially supination trauma, will injure the trochlea (Sneppen & Buhl 1974). In addition to its weightbearing function, the body of the talus is also the main component of the most important joints of the foot, the talocrural and the subtalar joints; in this capacity it is of decisive importance in the hinge movements and

rotation of the foot. Owing to its central functions, fractures of the talar body often involve appreciable disability, and this is further accentuated by the special vascularisation conditions which arise in certain regional injuries, involving a marked risk of avascular necrosis of the body (Haliburton et al 1958, Larsson et al 1961, Zifko & Wetli 1969, Mulfinger & Trueta 1970, Peterson et al 1974).

A basic requirement for planning optimal treatment of fractures affecting the body of the talus is of course an adequate knowledge of the prognosis of the various types of fracture, including their relation

Table 1 Previous reports published of fracture of the body of the talus

	No of fractures without displacement	No of fractures with displacement	Total
Schrock et al (1942)	0	15	15
Kleiger (1948)	7	3	10
Coltart (1952)	15	7	22
Mindell et al (1963)	3	7	10
Pennal (1963)	3	8	11
Kenwright & Taylor (1970)	4	2	6
Present material (1977)	21	30	51

to the occurrence of osteoarthritis and osteonecrosis. Such a selective prognostic evaluation can be made only on the basis of a large material of fractures after exclusion of cases with serious complicating associated regional injuries. However, fractures of the body of the talus are extremely rare, constituting only about 0.1 per cent of all fractures (Coltart 1952, Ballschew 1975). Consequently, the prognostic problems have so far been elucidated only on the basis of small series (Table 1) which do not fulfil the above-mentioned criteria.

With this background, it would seem of interest to study the prognosis of the various morphological types of fracture occurring in the body of the talus, on the basis of a major material having a sufficiently long follow-up period.

MATERIAL

The material is derived from the Directorate of Employment Accident Insurance, Copenhagen, where 218 cases concerning fractures of the talus were handled during the period 1945-1975. Of these fractures, 62 affected the body of the talus. This does not include cases of minor chip fractures or the osteochondritis-like trochlear injuries or ligamentous avulsion fractures whose prognosis differs essentially from that of other talar fractures.

In 28 cases there were associated injuries involving in 25 cases the same ankle and foot and 21 fractures of the ankle, two of the calcaneus and two of the metatarsal bones. In 11 cases the associated injury was of a serious nature and may have appreciably influenced the

prognosis. As the present study was intended to elucidate the prognosis of talar fracture alone, these 11 cases were excluded. This leaves 51 fractures of the body of the talus without serious associated injuries.

In all 51 cases an orthopaedic assessment was available based upon a clinical as well as a radiological examination. The orthopaedic assessments, X-ray films and case records were reviewed by the authors and form the basis of the present publication.

In age the patients ranged from 17 to 64 years, mean age 36. The follow-up period from the time of the accident until the time of the final specialist examination ranged from 9 to 76 months, mean 23 months.

In 32 of the 51 cases the fracture was due to falls from a height, while in eight cases there had been direct trauma, in five a distortion injury and in six cases traffic accidents.

Figure 1 gives the morphology of the various types of fracture. The compression fractures in the trochlea (A) involved only the medial or lateral part of the trochlea and exclusively the talocrural joint. There were two main types of shearing fractures of the trochlea: a coronal (B) and a more or less sagittal (C) one. The coronal type could be mistaken for fracture of the talar neck, but it was situated more posteriorly involving the trochlea and therefore could entail incongruence in the talocrural joint, often blocking dorsiflexion of this joint (Figure 2). Both types of shearing fracture involved the talocrural as well as the subtalar joints. The same applied to the minor fractures affecting the posterior (D) or lateral (E) tubercle. Marginal fractures not being included in the material as already mentioned. Comminuted crush fractures (F) entailed fragmentation of the entire trochlea with massive incongruence in the talocrural as well as subtalar joints (Figure 3).

The relation of the fracture types to the occurrence of displacement of the fracture and to the occurrence of subluxation in the adjacent

Types of fracture



A Compression fracture



B Coronal shearing fracture



C Sagittal shearing fracture



D Fracture in the posterior tubercle



E Fracture in the lateral tubercle



F Crush fracture

Figure 1

Joints is presented in Table 2. It will be seen that while a large number of the compression, shearing and crush fractures were displaced and sometimes involved subluxation, the majority of the fractures affecting the posterior and the lateral tubercle were not displaced.

Initial treatment had been in three cases

open reduction and fixation in six cases reduction and a plaster cast and in the remaining 42 cases only a plaster cast and/or non weight bearing.



Figure 2 Coronal shearing fracture anteriorly in the trochlea showing severe malunion. Subluxation as well as talocrural osteoarthritis. Follow-up period 20 months.



Figure 3 Crush fracture with severe fragmentation of the body.

Table 2 Type of fracture in relation to displacement and to subluxation in the subtalar and talocrural joints

Type of fracture	Fracture without displacement	Fracture with displacement	Fracture with displacement and subluxation	Total
Compression	0	10	0	10
Shearing	4	3	10	17
Posterior tubercle	10	1	0	11
Lateral tubercle	7	1	1	9
Crush	0	1	3	4
Total	21	16	14	51

RESULTS

The most important complications, from the prognostic point of view, were avascular necrosis, malunion, and osteoarthritis in the talocrural and/or subtalar joint.

Avascular necrosis In eight cases there was marked condensation of the trochlea. In seven of them, moreover, the trochlea was deformed by collapse, in two of the cases this deformity was very pronounced (Figure 4). Out of the eight cases of avascular necrosis, five occurred among the 13 displaced shearing fractures and three among the four crush fractures.

Malunion Thirty fractures of the talus body were primarily displaced—16 slightly, while 14 showed marked malalignment with a break of 3 mm or more in the joint surface or with crushing and deformity of major parts of the body. In 9 of these 14 cases, an attempt at reduction had been made initially, but the displacement could be reduced to mild in only four of the cases. This left 10 cases with severe (Figure 2) and 20 with slight malunion.

Osteoarthritis Twenty-eight patients developed osteoarthritis (Tables 3 and 4). This complication occurred with approximately the same frequency in all types of fracture except for those of the lateral tubercle which were followed by

osteoarthritis in only one case out of nine. It is worthy of particular note that among the 11 cases having fracture of the posterior tubercle eight were complicated by osteoarthritis. Relating the occurrence of osteoarthritis to malunion and to subluxation shows, as might be expected, that both predispose to osteoarthritis (Table 4).

Other complications Bony ankylosis in the subtalar joint occurred during the healing of one crush fracture complicated by osteonecrosis. There were two cases of skin necrosis and infection, one involving osteitis and long-lasting fistula.



Figure 4 Coronal shearing fracture anteriorly in the body complicated by osteonecrosis and severe deformity of the trochlea. Follow-up period 13 months.

Table 3 Occurrence of talocrural and subtalar osteoarthritis in relation to type of fracture

type of fracture	Talocrural osteoarthritis	Subtalar osteoarthritis	Talocrural and subtalar osteoarthritis	No osteoarthritis	Total
compress on	5	0	0	■	10
bearing	3	1	7	6	17
anterior tubercle	2	5	1	■	11
lateral tubercle	0	1	0	■	9
rush	1	0	2	1	4
Total	11	7	10	■	51

Table 4 Occurrence of osteoarthritis in relation to malunion or union in subluxation in the talocrural and/or subtalar joint

	Osteoarthritis	No osteoarthritis	Total
fracture united without displacement	9	12	21
fracture united with displacement	8	8	16
fracture united with displacement and subluxation	11	3	14
Total	28	23	51

Table 5 Subjective results

Type of fracture	Complaints			Total
	Minor or none at all	Moderate	Severe	
compress on	5	1	4	10
bearing	1	6	10	17
anterior tubercle	3	5	3	11
lateral tubercle	3	3	3	9
rush	0	0	4	4
Total	12	15	24	51

ion In three non union resulted from minor mainly intra articular bone fragments

joint Nine patients were later fitted with orthopaedic footwear

Secondary treatment

Because of secondary osteoarthritis and pain on weightbearing fusion was performed in four cases subtalar in three and talocrural in one In three cases a non united partially free bone fragment was removed from the talocrural

Subjective result

At the final follow up examination 39 patients still had complaints mostly in the form of pain in the ankle region and hindfoot on weightbearing From Table 5 it is apparent that these complaints manifested themselves not only after major fractures but to a large extent

Table 6 Influence of talar injury on occupational capacity

Type of fracture	Back to previous work	Obtained lighter work	Not working	Total
Compression	5	2	3	10
Shearing	6	6	5	17
Posterior tubercle	4	5	2	11
Lateral tubercle	4	3	2	9
Crush	0	4	0	4
Total	19	20	12	51

Table 7 Disablement assessment

Type of fracture	Disablement percentage				Total
	0	5-8	10-12	> 12	
Compression	2	5	1	2	10
Shearing	0	4	2	11	17
Posterior tubercle	0	5	6	0	11
Lateral tubercle	1	3	6	0	9
Crush	0	0	0	4	4
Total	3	17	14	17	51

also after the minor, mainly non-displaced fractures of the posterior and lateral tubercles

Rehabilitation

The occupational situation of 39 patients was permanently altered by the talar injury, and as shown in Table 6 there were considerable rehabilitation problems after fractures of the posterior and the lateral tubercles. Thus, out of 20 patients with injuries of this type, only eight were able to resume full employment in their previous occupation.

Disability assessment

One expression of the prognosis is the disablement percentage which is fixed in each case by the Directorate of Employment Accident Insurance and which forms the basis of the compensation. From Table 7, it can be seen that in the

various types of fracture the disablement percentage agreed with the subjective result and with the rehabilitation difficulties, as shown in Tables 5 and 6 respectively.

DISCUSSION

It is generally known that severe fractures of the body of the talus, including displaced shearing fractures and crush fractures, have a serious prognosis. Mundell et al (1963) reported good results in only two out of seven displaced fractures of the talar body, three of which developed osteonecrosis. Collart (1952) found osteonecrosis in five out of six displaced fractures of the body and reported a high incidence of post-traumatic osteoarthritis, especially in the subtalar joint. However, the results of the displaced intra-articular fractures appear to depend to some extent upon what degree of reduc-

tion is obtained (Coltart 1952, McKeever 1963, Kenwright & Taylor 1970)

As regards these severe fractures, the present study confirmed the previous results. We also found a high frequency of osteonecrosis, a high incidence of osteoarthritis which definitely seems to depend upon malunion and subluxation (Tables 3 and 4), and a late result characterised by appreciable subjective complaints (Table 5) and rehabilitation difficulties (Tables 6 and 7). The treatment of these fractures should be according to the current lines (Watson Jones 1962), but with great emphasis on an exact reduction and a stable fixation whenever possible, a procedure which often necessitates operation. Most authors have indicated a good prognosis in minor, mainly non-displaced fractures (Kleiger 1948, Mindell et al 1963, Kenwright & Taylor 1970). Only Coltart (1952) mentioned an appreciable frequency of late subtalar osteoarthritis following non-displaced fractures of the talus. The present study revealed a far more serious prognosis for the small, mainly non-displaced fractures of the posterior and lateral tubercles than has previously been assumed. This more serious prognosis was manifest, as regards fractures of the posterior tubercle, in a very high incidence of osteoarthritis (Table 3), and in the case of both types of fracture, in severe complaints (Table 5), rehabilitation problems (Table 6), and a fairly high disability assessment percentage (Table 7).

In our opinion the majority of these fractures, fairly negligible *per se*, form a link in more extensive regional injuries involving the talocrural and especially the subtalar joint. Thus, at the time of the accident there has been subluxation, and the consequent articular injury bears the main responsibility for the grave long term prognosis. We feel, therefore, that in treating fractures of the posterior and lateral tubercles it is important to aim at rapid normalisation of the func-

tion in the talocrural and subtalar joints. This is best obtained by fairly brief immobilisation which affords a possibility for the healing of the joint capsule and ligamentous structures. Thereafter, energetic active training of foot movement should be instituted. As these fractures invariably involve a weightbearing joint surface, the patients should not be allowed to bear weight on the foot until solid union of the fractures has been obtained.

REFERENCES

- Baltschew, G. (1975) Für und gegen Taloktomie oder Arthrodesse des Sprunggelenkes bei schweren Talusfrakturen. *Beitr Orthop* 22 94-96.
- Coltart, W. D. (1952) Aviators astragalus. *J Bone Jt Surg* 34-B, 545-560.
- Haliburton R. A., Sullivan, C. R., Kelly, P. J. & Peterson L. F. A. (1958) The extraosseous and intraosseous blood supply of the talus. *J Bone Jt Surg* 40 A 1115-1120.
- Kenwright, J. & Taylor, R. G. (1970) Major injuries of the talus. *J Bone Jt Surg* 52 B 36-48.
- Kleiger, M. (1948) Fractures of the talus. *J Bone Jt Surg* 30 A, 735-744.
- Larsson R. L., Sullivan, C. M. & Jones, I. (1961) Trauma, surgery and circulation of the talus—What are the risks of avascular necrosis? *J Trauma* 1 13-21.
- McKeever F. M. (1963) Treatment of complications of fractures and dislocations of the talus. *Clin Orthop* 30 45-52.
- Mindell, E. R., Cisek M. E., Kartalian G. & Dziob J. M. (1963) Late results of injuries to the talus. *J Bone Jt Surg* 45-A, 221-243.
- Mullinger, G. L. & Trueta, J. (1970) The blood supply of the talus. *J Bone Jt Surg* 52 B, 160-167.
- Pennell G. F. (1963) Fractures of the talus. *Clin Orthop* 30 53-73.
- Peterson, L., Goldie, I. & Lindell M. (1974) The arterial supply of the talus. *Acta orthop scand* 45 260-270.
- Schrock R. D., Johnson, H. F. & Walters C. W. (1966) The blood supply of the talus. *Acta orthop scand* 45 307-320.
- Weber, M. (1966) Die Verletzungen des oberen Sprunggelenkes. Hans Huber, Stuttgart.

Watson-Jones, R (1962) *Fractures and joint injuries* Livingstone London

Zifko, B & Wettig, H (1969) Behandlung und

Ergebnisse von Talusbrüchen und Talusverrenkungsbrüchen *Arch orthop Unfall-Chir* 65 65

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SUPINATION DEFORMITY OF THE FOREFOOT

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Supination deformity of the forefoot is rare. Observations of eleven cases and the production of the deformity in rabbits suggest that loss of function of the peroneus longus muscle in combination with the effect of a strong tibialis anterior muscle is decisive for the appearance of the deformity. Primary conditions causing deformity were spina bifida, talipes equinovarus, poliomyelitis, trauma and muscular dystrophy. Treatment by wedge resection of the first cuneiform and the first metatarsal bones and transfer of the tibialis anterior tendon was successful. Operations for supination deformity were carried out in nine cases.

Key words: foot deformity, hallux equinus, dorsal bunion.

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In 1937, one of the authors (A.L.) encountered for the first time a patient with a marked supination deformity of the forefoot, the hindfoot being in a neutral position (Case 7, Table 1). Since then the authors have seen 10 additional cases of this very typical but fairly rare deformity. A thorough search of the literature revealed that only five authors have given descriptions of it. Duchenne published a drawing of it in 1867 (Figure 7). He called it talipes planus varus and stated that it was a sequel to paralysis of the triceps surae, the peroneus longus and the flexors, in combination with an intact tibialis anterior muscle. In 1925, Hohmann described the deformity as isolated supination contracture of the forefoot. He wrote: "Hitherto I don't know about any description of this highly characteristic deformity."

In 1940 Lapidus described the deformity under the name "Dorsal Bunion

and recommended an operation which had been carried out in six patients with encouraging results. Lapidus wrote: "With the exception of Hohmann's classic book 'Fuss und Bein' the author has been unable to find any satisfactory description of it in the literature." Lapidus stressed that the dorsiflexed position of the first metatarsal bone plays an important part in the deformity and its correction.

In 1943 Hammond reported 42 examples of "elevation of the first metatarsal bone with hallux equinus." He wrote: "There is no doubt that this condition has been recognized by many observers but specific reference to it is rare in the available literature." In 1966, Palazzi et al., reporting the results of 1518 tendon transfers in paralytic feet, mentioned supination deformity of the forefoot as a complication in 18 cases after transfer of the peroneus longus tendon.

Watson-Jones, H (1962) *Fractures and joint injuries* Livingstone, London

Zifko, B & Wellig H (1969) *Behandlung und*

Ergebnisse von Talusbrüchen und Talusgelenkungsbrüchen Arch orthop Unfall-Chir
65, 65

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supination deformity of the forefoot

Date of birth	Right or left foot Age at operation for supination deformity (years)	Date of follow up	Figures Remarks
14th 1952	R (13)	Sept 27th 1973	Figure 1 A-C
19th 1945	R (21)	Oct 5th 1973	Figure 2 A-G
18th 1958	L (8)	Oct 9th 1973	Figure 3 A-C
11st 1958	R (8)	Sept 17th 1973	
10th 1957	R (10)	Sept 27th 1973	Figure 4 A-C
1st 1951	R and L (16)	Oct 29th 1973	Figure 5 A B
25th 1953	R and L Not operated	Oct 9th 1972	
9th 1947	L Not operated	Sept 27th 1973	Figure 6
15th 1952	R (16)	May 7th 1975	Figure 8 A-C
July 22nd 1959	R (16)	Oct 8th 1975	
Dec 29th 1964	R (9)	Oct 8th 1975	Only transfer of tib ant tendon

Table 1 Details of the 11 patients

Case no	Sex	Primary condition causing foot deformity	Operations and history before development of supination deformity of the forefoot
1	M	Spina bifida Sacral meningomyelocele Weakness of triceps surae especially on the right side	Right peroneal tendons and tibialis posterior tendon transferred to tendo calcaneus in 1952
2	M	Poliomyelitis Muscle weakness in right leg Calcaneo valgus deformity of right foot	Right peroneal tendons transferred to tendo calcaneus in 1952
3	M	Congenital equinovarus deformity of left foot Congenital ring constriction of left leg	Plastic operations on the leg for ring constriction in 1959-1960 Tenotomy of tendo calcaneus in 1960
4	M	Poliomyelitis in 1960 Palsy of right leg Peroneus longus and long flexors and long extensors of the toes completely paralysed	Extra articular subtalar arthrodesis <i>ad modum</i> Grice, transfer of the peroneus brevis to tendo calcaneus and abbreviation of the extensor hallucis longus tendon in 1961
5	F	Congenital equinovarus deformity of both feet	Tenotomy of the tendo calcaneus correct under general anaesthesia plaster treatment and derotation osteotomy of both legs in 1959 Lengthening of right tendo calcaneus in 1962 Operative soft tissue release and correction of right foot in 1963
6	F	Congenital defect of sacrum with muscle weakness in both legs Vertical talus deformity and supination deformity of the forefoot on both sides	Not operated on before correction of supination deformity of the feet Weakness of all muscles of the legs flexor hallucis brevis and extensor digitorum longus completely paralysed
7	M	Congenital muscular dystrophy Weakness of peroneal muscles on both sides Marked supination deformity of left forefoot slight supination deformity of right forefoot	Conservative treatment of feet in plaster in 1957 Triple arthrodesis of left foot with poor result in 1972
8	M	Cutting trauma from window glass to the upper lateral part of the left leg in 1955	After trauma progressive supination deformity of left forefoot Operations on the tendons 1965 and 1967 without correction of forefoot deformity
9	M	Congenital equinovarus deformity of the right foot	Operative soft tissue release lengthening of the tibialis posterior and flexor digitorum communis tendons and radical release of ligaments on the plantar side of the foot in 1962 After operation slowly progressing supination deformity of the forefoot Calcaneo navicular fusion present
10	M	Spina bifida Multiple anomalies of the lumbar spine	No operations for foot deformity Extirpation of lumbar hemivertebra with regain of trunk balance in 1968 No change in muscle power after operation
11	F	Semimalignant haemangioma in the peroneal region of the right leg	Resection of fibula peroneal muscles and long extensor muscles of the leg in 1971

Supination deformity of the forefoot

Date of birth	Right or left foot Age at operation for supination deformity (years)	Date of follow-up	Figures	Remarks
14th 1932	R (13)	Sept 27th 1973	Figure 1	A-C
9th 1945	R (21)	Oct 5th 1973	Figure 2	A-G
28th 1958	L (8)	Oct 9th 1973	Figure 3	A-C
21st 1958	R (8)	Sept 17th 1973		
29th 1957	R (10)	Sept 27th 1973	Figure 4	A-C
1st 1951	R and I (16)	Oct. 29th 1973	Figure 5	A-B
25th 1953	R and I Not operated	Oct 9th 1972		
9th 1947	I Not operated	Sept 27th 1973	Figure 6	
25th 1957	R (16)	May 7th 1975	Figure 8	A-C
22nd 1959	R (16)	Oct 8th 1975		
29th 1964	R (9)	Oct 8th 1975		Only transfer of tib ant tendon



Figure 1 Case 1 Spina bifida. A, Radiograph of right foot before operation at the age of 13 years. B, Radiograph of both feet before operation. C, Radiograph of right foot 2½ months after operation. Resected bone areas seen in A.

MATERIAL

The eleven patients with typical supination deformity of the forefoot seen by the authors are listed in Table I. From this Table it appears that several different aetiologies and therapeutic procedures in varying combinations have provoked the deformity.

In three cases the primary condition causing foot deformity was spina bifida (Cases 1, 6 and 10, Figures 1 and 5). In two of these the supination deformity of the forefoot developed before any operation had been performed on the foot and in one after tendon transfer. In three cases the primary condition was congenital talipes equinovarus (Cases 3, 5 and 9, Figures 3, 4 and 8). Radical soft tissue release with possible damage to the tendon of the peroneus longus muscle, had been performed in two of these cases and in one there was a congenital ring constriction of the leg with absence of function of the peroneal muscles. In two cases the deformity developed after poliomyelitis (Cases 2 and 4, Figure 2). In one of these the peroneus longus muscle was paralysed and in the other the peroneus longus tendon had been transferred to the tendo calcaneus.

In two cases the deformity developed after the function of the peroneus longus muscle had been lost in connection with trauma (Cases 8 and 11, Figure 6). In two of the cases the supination deformity of the forefoot was combined with calcaneus or calcaneovalgus deformity of the hindfoot (Cases 1 and 2, Figures 1 and 2) and in two with a vertical talus deformity (Cases 6 and 10, Figure 5). In one case the cause was muscular dystrophy (Case 7).

OPERATION

The main cause of the supination deformity of the forefoot seemed to be the elevation of the first tarsal and metatarsal ray caused by muscle imbalance during the growth period. Thus plantar wedge resection of the first cuneiform bone and of the base of the first metatarsal bone in order to bring the head of the first metatarsal bone into a normal position, seemed to be a logical procedure for correction of the deformity. A transfer of the tibialis anterior tendon to the middle of the dorsum of the foot also seemed necessary to prevent recurrence.

The operation described here was planned for the case seen in 1965 (Case 1, Table I). At that time the authors were not aware of the somewhat different method described by Lapidus. As the result in the first case was satisfactory, the operation was performed on nine feet with some individual variations. The age at operation varied between 8 and 21 years.

Operative technique

A longitudinal incision is made on the medial plantar aspect of the foot in order to expose the medial and plantar surfaces of the first cuneiform bone.

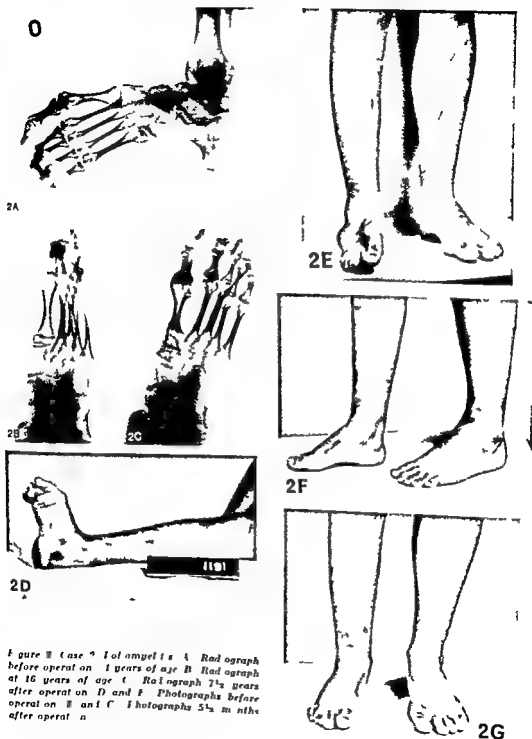


Figure 1 Case 1 Tolomy 13 A Radiograph before operation 1 years of age B Radiograph at 16 years of age C Radiograph 7 1/2 years after operation D and F Photographs before operation E and G Photographs 5 1/2 months after operation

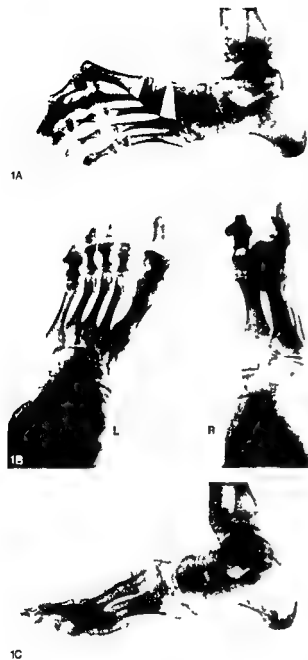


Figure 1 Case 1 Spina bifida A Radiograph of right foot before operation at the age of 13 years B Radiograph of both feet before operation C Radiograph of right foot 2½ months after operation Resected bone areas seen in A

MATERIAL

The eleven patients with typical supination deformity of the forefoot seen by the authors are listed in Table 1. From this Table it appears that several different affections and therapeutic procedures in varying combinations have provoked the deformity.

In three cases the primary condition causing foot deformity was spina bifida (Cases 1, 6 and 10, Figures 1 and 5). In two of these the supination deformity of the forefoot developed before any operation had been performed on the foot and in one after tendon transfer. In three cases the primary condition was congenital talipes equinovarus (Cases 3, 5 and 9, Figures 3, 4 and 8). Radical soft tissue release with possible damage to the tendon of the peroneus longus muscle, had been performed in two of these cases and in one there was a congenital ring constriction of the leg with absence of function of the peroneal muscles. In two cases the deformity developed after poliomyelitis (Cases 2 and 4, Figure 2). In one of these the peroneus longus muscle was paralysed and in the other the peroneus longus tendon had been transferred to the tendo calcaneus.

In two cases the deformity developed after the function of the peroneus longus muscle had been lost in connection with trauma (Cases 8 and 11, Figure 6). In two of the cases the supination deformity of the forefoot was combined with calcaneus or calcaneovalgus deformity of the hindfoot (Cases 1 and 2, Figures 1 and 2) and in two with a vertical talus deformity (Cases 6 and 10, Figure 5). In one case the cause was muscular dystrophy (Case 7).

OPERATION

The main cause of the supination deformity of the forefoot seemed to be the elevation of the first tarsal and metatarsal ray caused by muscle imbalance during the growth period. Thus planar wedge resection of the first cuneiform bone and of the base of the first metatarsal bone in order to bring the head of the first metatarsal bone into a normal position seemed to be a logical procedure for correction of the deformity. A transfer of the tibialis anterior tendon to the middle of the dorsum of the foot also seemed necessary to prevent recurrence.

The operation described here was planned for the case seen in 1965 (Case 1, Table 1). At that time the authors were not aware of the somewhat different method described by Lapidus. As the result in the first case was satisfactory, the operation was performed on nine feet with some individual variations. The age at operation varied between 8 and 21 years.

Operative technique

A longitudinal incision is made on the medial plantar aspect of the foot in order to expose the medial and plantar surfaces of the first cunei



4A



4B



4C

Figure 4 (Case 5) Congenital talipes equinovarus. A Photograph at the age of 3½ years before any treatment. B Photograph at the age of 10 before operation for supination deformity of the right forefoot. C Photograph aged 16 years 6 years after the operation.

Incised through the tendon sheath of the long extensor of the toes to the dorsum of the foot. An incision is made over the medial edge of the cuboid bone. The end of the tibialis anterior



5A



5B

Figure 5 (Case 6) Spina bifida. A Radiograph of right foot at 16 years of age, before the operation. B Radiograph of right foot 5¼ years after operation.

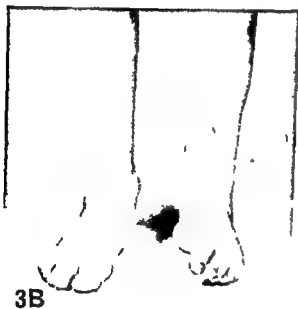


Figure 6 (Case 8) Deformity after traumatic rupture of peroneal tendons.

tendon is drawn to the dorsum of the foot and implanted by means of an intraosseal suture into the medial part of the cuboid bone. A plaster cast is applied from the toes to the knee. The foot is kept in plaster for 8 weeks.

RESULTS

The results of the operation are evident from the illustrations. The feet are, of course, by no means normal but the operation corrected the supination de-



*Figure 3 Case 3 (congenital talipes equinovarus)
A Photograph at the age of 1 year B Photo-
graph at age 8½ years of age before the opera-
tion C Photograph 7½ years after operation*

form bone and the base of the first metatarsal bone. The tendon of the tibialis anterior muscle is dissected from its insertion into the bones mentioned. A wedge of bone with its base on the plantar side is resected with a chisel from the first cuneiform bone without opening the adjacent joints (see Figure 1A). In some cases the deformity is corrected when the resection surfaces of the first cuneiform bone are brought together and fixed with a staple or a strong suture (Cases 3 and 4). When the correction is not sufficient another wedge is chiselled out from the base of the first metatarsal bone distal to the epiphyseal plate. In six feet correction of supination deformity of the forefoot was satisfactory after wedge resection of the two

bones (Cases 1 ■ ■ C right and left and 10). In one foot (Case 9 Figure 8) there was fusion of the calcaneus and the navicular bone. The supination deformity could not be corrected by resection of the calcaneo navicular bone. Bridge and triple arthrodesis had been performed in addition to wedge resection of the first cuneiform and the first metatarsal bones.

When the deformity has been corrected by wedge resection of the bones and the resection surfaces have been fixed against each other with staples or strong sutures, a longitudinal incision is made in front of the distal part of the leg in order to expose the proximal part of the tibialis anterior tendon. The tendon is drawn from its insertion into the wound in the leg and con-

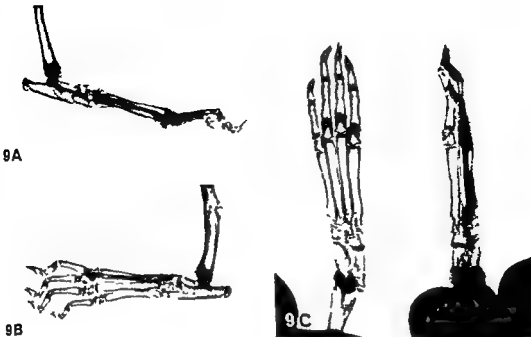


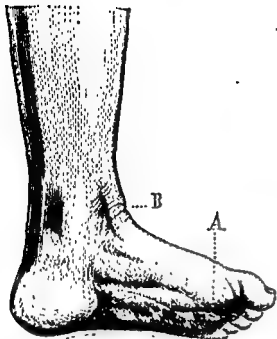
Figure 9 Rabbit A: Side view radiograph of normal foot of growing animal B: Side view radiograph of foot some weeks after section of peroneal muscles and tenodesis of Achilles tendon Compare with Figures 1 A and 5 A C: Dorso-plantar radiographs corresponding to A (normal) and B (supination deformity of the forefoot) Compare with Figures 1 B and 2 B

bits were less than 3 weeks old when operated on, the developing deformity was more severe than if they were 4 to 6 weeks old. Figure 9 A C shows the typical deformity produced in the rabbit.

The experiments support the idea that loss of function of the peroneus longus muscle in combination with the effect of a strong tibialis anterior muscle is decisive for the appearance of supination deformity of the forefoot.

REFERENCES

- Duchenne, M. B. (1867) *Physiologie des mouvements* p. 489 J-B Baillière et fils Paris
 Hammond, G. (1943) Elevation of the first metatarsal bone with hallux equinus *Surgery* 13, 240-256
 Hohmann, G. (1951) *Fuss und Bein* pp. 72-73 J. F. Bergmann München
 Lapidus, P. W. (1940) "Dorsal Bunion" Its mechanics and operative correction *J. Bone Jt. Surg.* 22, 627-637
 Palazzi, S., Madrigal, J. J., Nicoy, J. & Palazzi, S. Jr. (1966) Pie paralitico *Rev. Ortop. Traum. (Madr.)* 10, 217-323



7P

Figure 7. Picture published by Duchenne in 1867 "Pied plat varus" from palsy of triceps surae, peroneus longus and toe flexor muscles.



8B



8C

Figure 8 Case 9. Talipes equinovarus A. Photograph of right foot before operation at the age of III B. Radiograph of right foot before operation, C: Radiograph of right foot 6 months after operation

formity in all nine feet operated on. In no case was there any pain or functional disturbance, which could be ascribed to the operation, when follow-up examination was done.

SUPINATION DEFORMITY OF THE FOREFOOT PRODUCED EXPERIMENTALLY IN THE RABBIT

In connection with a study of the effect of tenotomies on the feet of growing rabbits, one of the authors (V.R.) found that isolated supination deformity of the forefoot regularly appeared after certain procedures. This deformity was seen in 21 rabbits and the common factors in all these experiments were that the peroneal tendons had been cut and the tibialis anterior had been left intact. If the rab-

THE RESULTS OF 41 BELOW KNEE AMPUTATIONS (SAGITTAL TECHNIQUE) IN RELATION TO LOCAL SKIN PERFUSION PRESSURE

Per Lund & Philip Sager

The material consisted of 68 per cent males and 32 per cent females. Forty four per cent were diabetics. The average age was 71.7 years (range 45-85 years). Preoperatively the local arterial skin perfusion pressure in the area of amputation (external counterpressure isotope technique) was measured in all patients.

There were 10 (24.4 per cent) femoral re-amputations. Six out of 16 patients (37.5 per cent) with preoperative skin blood pressures below 40 mmHg underwent re-amputation and 4 out of 10 (40 per cent) with pressure above 40 mmHg. Re-amputation was more common in diabetics (33.3 per cent) than in non-diabetics (17.4 per cent). In all cases of re-amputation there was concomitant infection leading to re-amputations even in patients with a good local blood supply.

FRACHTURA TALII

J. F. Lorentzen & O. Krogsaeg

A total of 123 patients with fracture of the neck of the talus were followed up with a mean observation time of 22 months. The distribution of the 123 fractures was as follows: 54 fractures of the neck without dislocation, 53 fractures with dislocation and subtalar luxation or subluxation and 16 fractures with dislocation and simultaneous luxation of the trochlea in the ankle joint as well as in the subtalar joint. The results were: 26 patients (21 per cent) developed avascular necrosis of the trochlea resulting in severe osteoarthrotic changes, 38 patients (31 per cent) developed talocalcaneal arthrosis and 58 (47 per cent) subtalar arthrosis. 87 (71 per cent) expressed moderate or pronounced complaints. For 74 patients (60 per cent) the fracture meant a change of employment or disability.

SUBTALAR DISLOCATION

Søren Bach & Christensen

Thirty three subtalar dislocations were reported. An account was given of the typical fractures following the lesion with special reference to the mechanism and consequences of fracture of the process of posterior talus.

The long term prognosis in this material seems to be worse than is generally assumed to be the case. Two patients had avascular necrosis followed by panarthrosis and a further 13 patients had radiological arthrosis in the subtalar joint. Clinically 23 patients had pain during

strenuous activities and 15 patients had a limp.

The incidence of arthrosis in the dislocations without fractures is surprisingly high and a comparison of the immobilisation periods suggests that early mobilisation will reduce the risk of arthrosis.

THE HEALING OF BELOW KNEE AMPUTATIONS IN RELATION TO PERFUSION PRESSURE OF THE SKIN

E. Hammersgaard & K. Baadsgaard

Sixty nine below knee amputations utilizing a long posterior musculocutaneous flap were performed on 67 patients with occlusive arterial disease.

Nine patients had skin necrosis and deep infection. Six had to be re-amputated above the knee. The frequency of re-amputations was thus 9 per cent. The mortality was 15 per cent.

In 56 cases skin perfusion pressure 10 cm below the knee was measured preoperatively. Among 50 cases with a pressure > 30 mmHg only one had to be re-amputated. Of the 6 patients with a pressure < 20 mmHg two had to be re-amputated.

BLADDER FUNCTION AFTER HEMIPELVECTOMY

T. Gerstenberg, J. Ross Nielsen, M. Lykkegaard Nielsen & L. Palm

A urological follow up of 7 patients was performed 5-30 months after hemipelvectomy. The follow up included cystometry, urodynamic investigations, a pyelogram, micturition-cysto-

metric and urodynamic investigation showed no neurogenic bladder dysfunction. It is concluded that a possible unilateral denervation of the bladder does not result in disturbances of bladder function.

LATE ULNAR PALSY ETIOLOGY, PATHOGENESIS AND MICROSURGICAL TREATMENT

Ole Sogaard

Late ulnar palsy which has been recognized since the beginning of the 19th century can be roughly divided into two etiological groups: one group having sustained an adequate trauma of the elbow region or a deformation of the elbow and an "idiopathic" group. In both groups a connective tissue mass is found in the nerve constricting the nerve fascicles, and by a new microsurgical method this tissue can be removed.

PROCEEDINGS OF THE DANISH ORTHOPAEDIC SOCIETY

April 30, May 1, 1976

FRACTURE OF THE TALUS A STUDY OF ITS GENESIS AND MORPHOLOGY

Otto Sneppen

In a material of 7192 ankle fractures and 218 talar fractures and/or subtalar dislocations, there were 59 cases of combined ankle and talar fracture. On the basis of a classification of the ankle fractures, it could be concluded that the position of the foot at the moment of injury is of decisive importance for the frequency of occurrence of talar fractures and dislocations. Supination in particular predisposed to fracture of the neck and trochlea of the talus as well as to subtalar dislocation.

SPINAL FUSION

F. Buus & S. Pilgaard

A follow up of 57 patients who had spinal fusion performed during the period 1949 to 1962 is presented. The diagnoses were: polyomyelitis, 37 cases, congenital scoliosis, 8 cases, idiopathic scoliosis, 10 cases, Recklinghausen's disease, 1 case and muscular dystrophy, 1 case.

In 25 cases the major curve was between 40 and 69°, in 32 cases 70 to 100°. The curves were corrected in a Rizzler jacket and fused through a window in the cast. The small joints were not opened and bank bone was used. The patients were kept recumbent in casts for 10-12 months postoperatively.

The loss of correction found was less than 30 per cent in 12 cases, from 30-60 per cent in 27 cases and from 60-100 per cent in 10 cases. Six patients had, postoperatively, a greater curve than before treatment. In spite of the great loss of correction only 12 patients complained of back pain, 38 were working and seven were receiving disability pension. The operative procedure has since been altered.

A PHOTOELASTIC STUDY OF HIP NAIL PLATES

J. Steen Jensen

Photoelastic studies of an acrylic model of the upper femur were demonstrated. The authors' standard model had a femoral inclination of 5°. The resultant hip pressure was found to act at 6° inclination and the abductor muscle pull at 20° inclination with the vertical. The abductor pull was found to be 0.57 times the hip pressure.

Photoelastic studies of Jewett nail plates with 125°-160° angulation were presented.

In osteosynthesis the largest possible nail plate angle is recommended, in order to reduce the strain on the nail plate.

A PHOTOELASTIC STUDY OF OSTEOSYNTHESIS OF UNSTABLE TROCHANTERIC FRACTURES USING HIP NAIL PLATES WITH DIFFERENT ANGLES

J. Steen Jensen

Acrylic models of unstable trochanteric fractures osteosynthesized with Jewett nail plates at angles of 125°, 140° and 160° were demonstrated. Photoelastic studies confirm that the largest possible nail plate angle should be used to reduce the strain on the nail plate junction.

RECURRENT DISLOCATION OF THE ELBOW

Torben Weeke

Three cases of recurrent dislocation of the elbow encountered since 1968 are reported. They were treated at the Orthopaedic Hospital, Dept. 2, Copenhagen. An anamnestic survey of the cases is given. They were operated *ad modum* Reichenheim & King, all with good result. A survey of the 56 cases contained in 28 reports in the literature since 1871 is given.

Because of Reichenheim's rather complicated exposure of the elbow and problems with scar ring on the front of the joint, we recommend the method of Osborne & Cotteril, which has been reported to have been successful in eight cases.

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BLADDER FUNCTION AFTER HEMIPELVECTOMY

T Gerstenberg J Ross Nielsen M Lykkegaard Nielsen & I Palm

A urological follow up of 7 patients was performed 5-90 months after hemipelvectomy The follow up included cystometry urodynamic investigations cystelogram micturition cystourethrography and cystoscopy

All patients had at the time of the follow up clinically normal micturition and the cystometric and urodynamic investigation showed a neurogenic bladder dysfunction It is concluded that a possible unilateral deprivation of the bladder does not result in disturbances of bladder function

ELATY ULNAR PALSY

PTIOLOGY PATHOGENESIS AND MICROSURGICAL TREATMENT Ole Gsgaard

Late ulnar palsy which has been recognized since the beginning of the 19th century can be roughly divided into two etiological groups one group having sustained an adequate trauma of the elbow region or a deformation of the elbow and an "idiopathic" group In both groups a connective tissue mass is found in the nerve constricting the nerve fascicles and by a new microsurgical method this tissue can be removed

by microdissection of the fascicles. In most cases clinical and neurophysiological recovery is achieved 11 months after the operation.

OCCLUDE PATTELLA LUXATION

Klaus Jacobsen & Peter Mel

In 10 patients admitted with haemarthrosis of the knee denying earlier or recent patellar dislocation we found during operation and with radiography the pathognomonic signs of this condition. An immediate spontaneous reduction had taken place.

THE PROGNOSIS OF NERVE LESION IN THE VOLAR CARPAL REGION

Henning Oetgaard Nielsen & Jørgen Laurit sen

Over a 7 year period 19 lesions of the median nerve 5 of the ulnar nerve and 7 of both nerves were repaired. Twelve were treated by primary traumatic suture and the remaining 15 by secondary repair but nerve grafting was not used. There were 16 cases of lesion of the finger flexors. Twenty three patients were reviewed. All had regained protective sensation of touch and function of the sweat glands but only 9 could discriminate below 2 mm and had regained some stereognosis. All repaired tendons were functioning perfectly. All the children had recovery completely. Of the 18 adults 11 had returned to their former job while 3 now had another full time job.

SHOULDER ARTHROGRAPHY AS A METHOD FOR DIAGNOSIS OF ROTATOR CUFF LESIONS

Frit Martin Jensen

The diagnosis of traumatic as well as degenerative shoulder pain can be difficult. Shoulder arthrography which can be performed in the ambulatory patient without risk or appreciable discomfort is an important diagnostic tool.

Out of 175 shoulder arthrographies only eight resulted in mild discomfort.

Shoulder arthrography in a group of 18 patients with long term loss of mobility after shoulder injury showed rotator cuff lesion in 16 cases. The patients had been treated initially in an emergency room without the diagnosis having been made clinically. The prognosis was poor as eight patients never attained active mobility and three patients only attained active mobility up to 90°.

The importance of an early diagnosis of rotator cuff lesions must be emphasized even when operative treatment is not being considered.

A FOLLOW UP STUDY OF TIBIAL SHAFT FRACTURES. COMPARISON OF CONSERVATIVE TREATMENT AND OSTEOSYNTHESIS WITH CONVENTIONAL PLATES AND ASIF PLATES

J. Steen Jensen, F. Wang Hansen & J. Johansen

A total of 238 tibial shaft fractures were reviewed after a mean observation time of 35 years. 102 fractures were treated conservatively. Osteosynthesis was performed using conventional plates in 41 cases, ASIF plates in 64 and other methods were used in 31 cases.

At the follow up malpositioning was encountered in 21 per cent of the conservatively treated and in 10 per cent with conventional plates.

In closed fractures there was non union in 6 per cent of the conservatively treated and in 8 per cent of those treated with conventional plates. There were 4 per cent with deep infection with conventional plates as against 5 per cent with ASIF plates.

In compound fractures conservative treatment led to 21 per cent with non union and 3 per cent with deep infection. With ASIF plates there were 11 per cent with deep infection and 1 with conventional plates 24 per cent with non union and 12 per cent with deep infection.

ASIF plate osteosynthesis was found to be justified in the treatment of tibial shaft fractures.

SCOLIOSIS TREATED WITH HARRINGTON INSTRUMENTATION

F. Horlyck & F. Thomsen

Since 1972 at the Orthopaedic Hospital in Aarhus 37 cases of scoliosis have been treated with posterior fusion and internal fixation using Harrington instrumentation. The average preoperative curve was 73°. The results in 25 patients with an observation period of more than 1 year show an average initial postoperative correction of 45 per cent of the preoperative angle. Walking with a Milwaukee brace is started after 6 weeks and the brace is used for 1 year after the operation.

During the first year the loss of correction varied from 0 to 23° so that the final average correction was 33 per cent of the preoperative angle. There were no cases of pseudarthrosis.

ATLANTO AXIAL INTERLAMINAR FUSION

K. Harry Sørensen & Jakob Husbj

Thirty six patients were treated with atlanto axial interlamellar fusion utilizing a special technique and team work between neurosurgeon and orthopaedic surgeon. Two bone grafts from

the iliac crest with grooves for the two laminae were fixed with steel wires

Twenty-one patients had a fracture of the dens axis (5 pseudoarthrosis) and 10 rheumatoid arthritis (7 horizontal and 5 vertical dislocation) 8 had medullary symptoms Five had other lesions

All fusions were solid at follow up at least 1 year after the operation Great relief of symptoms was achieved with a minimum of restriction of movement of the cervical spine

ANTERIOR LUMBAR INTRACORPOREAL FUSION

K Harry Sorensen

Ninety eight patients had fusion performed (extraperitoneal technique) Indications were incapacitating low back pain caused by degeneration of the 4th/5th lumbar discs or spondylolisthesis 133 discs were degenerated 114 were fused There were no complications in 75 per cent However 11 had thrombophlebitis

2 fatal pulmonary embolism 4 slight infarctions and 3 severe atelectasis

At follow up 3-8 years later, the fusions were solid in 91 per cent and after re operation in 94 per cent Healing was not achieved in 21 per cent of the patients with spondylolisthesis 73 per cent felt better or cured 31 patients had constant pain (21 somatic explanation) 60 per cent of patients operated upon after the age of 45 received disablement pension

MODULAR KNEE PROSTHESIS

N O Christensen

In contrast to the hinge type of knee prosthesis (Waldius Guepar etc) the modular type of prosthesis (Marmor St Georg) uses minimal amounts of foreign material and allows for only one compartment of the joint to be replaced as this is generally sufficient Severe instability and angulation can be treated effectively in this way The patients are walking after 1-2 days In rheumatoid arthritis both compartments must be replaced in most cases

PROCEEDINGS OF THE FINNISH ORTHOPAEDIC ASSOCIATION

25th Anniversary Meeting

Helsinki, Finland, 13 November 1976

EDITOR A ALHO

STUDIES OF POSTOPERATIVE METABOLISM IN THE KNEE USING INTRA-ARTICULAR FLUID ANALYSIS

S Finola & J Auniloski

Department of Surgery

Turku University Central Hospital

Under normal conditions the synovial membrane is well vascularized and acts as a dialyzing membrane between the joint cavity and the circulation. In arthritis the tissue environment becomes more ischemic and this may result in chondrocyte damage and even death at the articular surface. The response of synovial tissue metabolism to surgical trauma was investigated using postoperative synovial fluid analysis after two types of operation, medial meniscectomy and synovectomy. Analyses were also performed in nonoperated patients with traumatic effusion or chronic synovitis of the knee. It was found that the knee joint metabolism in chronic synovitis is shifted towards anaerobic glycolysis in both operated and nonoperated patients whereas meniscectomized and traumatic knees are considerably more capable of maintaining oxidative metabolism.

BASAL OSTEOTOMY OF THE FIRST METATARSAL BONE IN HALLUS VALGUS EXPERIENCES WITH THE USE OF AO PLATE

J Avikainen, T Tervo, H Vaherto & P Rokkanen

Orthopaedic Department

Central Hospital of Central Finland

Jyväskylä

For young patients osteotomy operations are frequently considered together with excision of the exostosis. A less favoured osteotomy method has been the basal laterally based wedge osteotomy, which was first introduced by Loison (1901) and Balacescu (1903). However, this operation is able to correct the metatarsus

primus varus quite efficiently. To stabilize the correction we have added a small AO plate for fixation. In addition plaster of Paris has been applied for 6 weeks. In 33 patients, 46 feet were operated on. There were 31 women and 2 men. Only two of the patients were over 50 years of age. Pain was the most frequent indication. A follow up was made an average of 15 years post-operatively. Subjective results were good in 30 cases, fair in 9 and poor in one. Objectively the results were good in 36 cases and fair in 9. The follow up of one patient is not yet completed. The mean period off work was 7 weeks. Metatarsus varus angle was reduced from 14.8° to 9.3° and hallux valgus angle from 33.2° to 17.7° . Mt I-II distance was reduced from 13.7 mm to 10.2 mm. One wound infection was registered and one patient had postoperative oedema. A good functional and cosmetic result was achieved in most of the cases.

UPPER EXTREMITY DEFORMITIES COMBINED WITH OROFACIAL CLEFTS

Jappu Uuspa

Finnish Red Cross Cleft Centre

The series consists of 89 cases with upper extremity deformities among the 3 225 cleft patients born during the period 1950-75 and treated at our centre (see Table). Two thirds of the patients had a cleft palate, including half of the males and nearly all of the females. The percentage of upper extremity deformities in the different types of orofacial clefts was as follows: cleft lip 0.8, cleft lip and palate 1.6 (cleft of the secondary palate 3.5), branchial arch syndrome (lateral cleft) 5.2, the total average was 2.8 per cent. One third of the patients were dwarfs, most of them diastrophic dwarfs. Only 11 cases of syndactylia, more complicated than average and among them four cases of Apert syndrome, were noted. The number of polydacty-

tylia cases was also exceptionally low. Ten of the thirteen ectrodactylia/melia cases had multiple deformities. Three quarters of the 89 patients had other multiple deformities.

	Male	Female	Total
Oro-facial clefts	1 614	1 611	3 225
- Upper extremity deformities	53	36	89
- Dwarfs	16	15	31
- Pterygium syndromes ¹	6	4	10
- Down syndrome	6	-	6
- Syndactylia	7	4	11
- Polydactylia	3	1	4
- Ectrodactylia/melia	7	6	13
- Brachydactylia	2	2	4
- Others ²	7	6	13

¹ Alipfel Feil Sprengel Bonnevie Ulrich Caderla Stern etc

² Symphalangism clinodactylia flexion contractures nail deformities etc

SPINAL FUSION AND THE CORRECTION OF

Helsinki

Experimental attempts to produce solid fusion of the growing spine with bone grafts have generally been unsuccessful. Spine fusion experiments have therefore failed to shed much light on the clinical problems of early spine fusion. Continued growth in the length of the spines of young rabbits routinely occurs after spine arthrodesis in which gross pseudarthroses have developed at each interspace.

In our earlier studies a bony fusion was achieved in different regions of the thoracic and lumbar spine with free periosteal transplants. In unilateral fusions this caused a progressive scoliosis.

In the present study this new model of spinal growth disturbance was used in attempts to correct experimental scoliosis. When a progressive scoliosis developed a free periosteal graft from the tibia of the same animal was transplanted to the convex side of the spine between the spinous and articular processes overlying the vertebral laminae.

With this method it was possible to achieve spinal fusion and stop the progression of experimental scoliosis. We conclude that with an early fusion a gradual straightening of slight or moderate scoliosis is possible.

SPINAL FUSION OF IDIOPATHIC SCOLIOSIS WITH FREE PERIOSTEAL GRAFTS

A PRELIMINARY REPORT

O Snellman K Osterman & J Ritala

Orthopaedic Hospital of the Invalid Foundation Helsinki

The present operative treatment of progressive idiopathic scoliosis generally consists of the Harrington method and spinal fusion. The Harrington instrumentation gives a rigid fixation. In our previous studies free periosteal grafts have proved to possess a strong and fast bone forming capacity both experimentally and clinically.

These observations led us to use free periosteal grafting in spinal fusion of scoliosis and spondylolisthesis.

The osteoperiosteal grafts were taken from the tibia with a sharp chisel. In this way it was possible to utilize the cambium layer cells and also the maximal growth potential of the graft.

A total of 55 patients were operated on. The mean age of the patients was 14.5 years. The fusion was performed in thoracic thoracolumbar or lumbar areas. In 44 patients the indication for fusion was idiopathic scoliosis. The patients were allowed to walk on the second postoperative day with a Milwaukee brace and the brace was used for 6 months postoperatively.

Biopsies were taken during a second operation (4, 6, 8, 12 and 24 weeks after the transplantation).

The bone formation in the fusion area occurred through an enchondral process. It was stable and compact after 24 weeks (6 months).

HAEMATOMA OF THE ROOT SLEEVE

J M Huittinen

Hyökykylä Rehabilitation Centre

Helsinki

In a postmortem study aimed at the evaluation of lumbosacral nerve injuries in fractures of the pelvis a laminectomy was performed.

The root sleeve was a round subdural haematoma with a diameter of 2 cm which appeared at the site of the posterior root ganglion. Histologically a cystic cavity around the spinal ganglion and an acute haemorrhage at the site of both roots were seen.

The traumatic haemorrhage of the root sleeve thus occurred at the junction of the nerve root and the spinal nerve. Here the meningeal arrangement of the nerve root sleeve ends and the subarachnoid space does not extend beyond the spinal ganglion. The haematoma in the root

sleeve may compress the nerve roots which are less resistant to compression than the peripheral nerves themselves

These subdural haematomas on the sacral nerve root sleeves appeared to be caused by bleeding into a perineurial cyst. The cysts cannot be demonstrated by an ordinary lumbar myelography. A traumatic haemorrhage into the sacral perineurial cyst produces an expansion of the cyst and a compression of the nerve root. This mechanism of neurological defects as a complication of injuries to the lumbosacral spine and pelvis has not been described earlier.

THE TREATMENT OF LESIONS OF THE PLEXUS BRACHIALIS: A PRELIMINARY REPORT

A. Solonen & S. Tikki

Section of Hand Surgery

Orthopaedic Hospital of the Invalid Foundation
Helsinki

Twenty five patients with plexus brachialis lesions were treated during the period November 1972–July 1976. The injuries were mainly traumatic lesions from traffic accidents. Careful pre-operative examinations such as tests of muscle functions and sensibility, EMG, cervical myelography and histamine axon reflex studies were made.

The type of operation selected was a free nerve transplantation in 15 cases, suture of the plexus in one case, liberation in five cases and transposition of some intercostal nerves into the plexus in four cases. There are some encouraging results among the patients operated on during 1973–1974 but it is still too early—because of the

long regeneration time—to make any firm conclusions about the usefulness of these painstaking operations which demand the teamwork of two orthopaedic surgeons and one micro surgeon and a good deal of time in the operating theatre.

FRACTURES OF THE OLECRANON: AN ANALYSIS OF 37 CONSECUTIVE CASES

O. Aiviluoto & S. Santavirta

Division of Orthopaedics and Traumatology
Surgical Hospital

Helsinki University Central Hospital

Thirty seven olecranon fractures were treated from 1973 to 1975. Fifteen of the fractures were transverse, five oblique and 18 comminuted. The treatment was operative in all but two cases. Three cases were complicated by a superficial infection and in three cases the internal fixation failed. The mean follow up time was 2 years.

The results were evaluated as excellent in 13 cases, good in 7, fair in 13 and poor in two cases. Patients under 50 years did better than older ones and the results for men were better than those for women. The transverse fractures healed as expected more satisfactorily than the comminuted ones. In the comparison of methods of internal fixation, cerclage combined with two Kirschner wires was better than cerclage alone. An immobilisation of 3 weeks or less gave the best results.

We suggest that internal fixation with two Kirschner wires and cerclage should be the method of choice in most cases. Immobilisation should not exceed 3 weeks.

PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

EDITOR ARNT JAKOBSEN

Oslo, September 25th, 1976

A DISCUSSION OF THE MECHANICS OF CURVE DEVELOPMENT IN IDIOPATHIC SCOLIOSIS

James A. Ashton Miller

Sophies Minde Orthopaedic Hospital
Oslo

Variables affecting the mechanics of curve
development in idiopathic scoliosis were dis-

cussed. The simple analogy of a slender elastic
rod loaded in axial compression was used. Axial
forces were assumed to consist of both muscular
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phasis was placed on the concept of structural
stability. Modifications of the simple analogy
to account for some of the anatomical and
physiological properties of the spine *in vivo*
were also discussed.

Oslo, October 22nd-23rd 1976 (Annual Meeting)

SPONTANEOUS OSTEONECROSIS OF THE HUMERUS

Ute Lippheim

Kronprinsesse Märthas Institutt
Oslo

Spontaneous osteonecrosis of the medial fem-
oral condyle in the absence of known disposing
factors chiefly affects persons aged 50 years
and over.

There is a sudden onset of pain. Radiographic
changes develop 4-5 months later. There con-
sist of flattening of the condyle, a sub-
chondral radiolucent line with a sclerotic halo
and a necrotic bone plate in the defect. The
changes are located on the weightbearing sur-
face of the condyle.

Before the development of radiographic
changes the diagnosis can be confirmed by
radioisotope scintimetry. Small lesions with
high focal scintimetric activity have the best
prognosis as regards the development of osteo-
arthritis. High tibial wedge osteotomy with
vagitation or prosthetic replacement surgery
may be necessary.

Three cases with typical symptoms and find-
ings were demonstrated.

THE CHANGED PATTERN OF BONE AND JOINT TUBERCULOSIS IN NORWAY

Bernhard Paus

Martina Hansens Hospital
Sandvika

The reduced incidence and the change in the
affected age groups in bone and joint tubercu-
losis in Western countries are well known. In
addition there are other but less conspicuous
changes. Multiple lesions and involvement of
the spine and sacro-iliac joint are now more
seldom while trochanteric involvement occurs
more frequently. In spinal cases the lesion is
more often localized to the dorsal region than
before. All these changes may be due to the
change in age distribution of the patients.

MECHANICAL PROPERTIES OF CORTICAL BONE

Terje Terjesen

Regional Hospital
Trondheim

Tension tests were performed on human cor-
tical bone from the femoral diaphysis, removed
during routine autopsy of 10 individuals aged
15 to 85.

Four different strain rates were used which
gave fracture after 5 minutes at the slowest
velocity and $1/10$ of a second at the fastest.
With increasing strain rate ultimate stress in-
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Ulf Uppheim

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Oslo

Spontaneous osteonecrosis of the medial femoral condyle in the absence of known disposing factors chiefly affects persons aged 60 years and over.

There is a sudden onset of pain. Radiographic changes develop 4-6 months later. These consist of flattening of the condyle, a subchondral radiolucent line with a sclerotic halo and a necrotic bone plate in the defect. The changes are located on the weightbearing surface of the condyle.

Before the development of radiographic changes the diagnosis can be confirmed by radionuclide scintimetry. Small lesions with high focal scintimetric activity have the best prognosis as regards the development of osteoarthritis. High tibial wedge osteotomy with valgisation or prosthetic replacement surgery may be necessary.

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Four different strain rates were used which gave fracture after 5 minutes at the slowest velocity and at $1/10$ of a second at the fastest. With increasing strain rate ultimate stress increased but no difference was found in ultimate

strain There was no difference between the age groups above and below 60 years as regards average ultimate stress. Ultimate strain decreased significantly with increasing age. This indicates that cortical bone in young individuals tolerates greater deformation before fracture than bone in older persons.

LARSEN'S SYNDROME

Helge Rønningen

Sophies Minde Orthopaedic Hospital
Oslo

Larsen's syndrome includes facial abnormalities, laryngotracheomalacia and multiple dislocations. One case, a female, is reported. She had a depressed nose bridge and widely spaced eyes, a dislocated right knee, bilateral pes equinovaginus and pectus excavatum. Radiographs showed an additional ossification centre of the calcaneus. Laryngoscopy showed laryngomalacia.

Mors subita supervened at 9 months of age in a state thought to be a cyanotic attack. Autopsy revealed a marked laryngo-tracheomalacia with soft flappy epiglottis and a tendency to tracheal collapse.

TREATMENT OF PERTROCHANTERIC FRACTURES WITH KUNTSCHER'S CONDYLOTROCHANTERIC INTRAMEDULLARY NAIL AND McLAUGHLIN'S PLATE AND NAIL

Astor Reigstad, Pål Denum & Gunnar W. Vestby
Ullevål Hospital
Oslo

A retrospective comparative study of 107 patients treated with McLaughlin's plate and nail and 104 with Kuntscher's intramedullary nail for pertrochanteric fractures is reported. Mean hospital stay was 34.1 and 20.5 days respectively ($P < 0.001$), the mortality within 3 weeks after operation 8.4 and 7.7 per cent. The mean duration of the anaesthesia was 111 and 81 minutes respectively ($P < 0.001$), the mean operating time 67 and 38 minutes ($P < 0.001$). Patients treated with McLaughlin's method needed significantly more blood transfusions than those who had Kuntscher's nail. Consolidation of the fracture occurred within 8 weeks in 68.6 and 87 per cent ($P < 0.01$) of the patients respectively, whereas healing periods exceeded 12 weeks in 20 and 29 per cent respectively. Penetration of the nail through the head/neck of the femur occurred most often in the patients with intramedullary nailing. Complications which severely affected the patients during the healing period or influenced the final result occurred in 22.5 and 16.7 per cent respectively. Pain and stiffness of the hip joint

occurred in patients with Kuntscher's nail and there were less problems mobilizing the patients after this operation. There were considerable complaints regarding the knee in 11 patients in this group, all recovering after removal of the nail.

It is concluded that Kuntscher's method is superior to the plate and nail method in pertrochanteric fractures. The former procedure is simple, provides stable fixation and fast healing.

TORSION DEFORMITIES FOLLOWING TRACTION TREATMENT OF FEMORAL FRACTURES IN CHILDREN

P. Denum, K. Ertresvåg & A. Høiseth
Regional Hospital
Trondheim

The torsion of both femurs was investigated in 55 patients who had been treated 5 to 13 years earlier at the age of 1 to 16 years for femoral shaft fractures. By comparing the anteversion angle of the contralateral hips determined by the Rippstein method, torsion deformities exceeding 10° were found in the fractured femur of 10 patients. The maximal deformity was $+27^\circ$. Deformities appeared more frequently in patients treated with adhesive overhead traction of the fractured leg than in patients treated with wire traction with the limb placed on an oblique frame. There was no correlation between age at the time of injury and torsion deformities, and no correlation between the length of the observation period and torsion deformities.

ON THE MECHANICS OF CURVE DEVELOPMENT IN IDIOPATHIC SCOLIOSIS

James A. Ashton Miller
Sophies Minde Orthopaedic Hospital
Oslo

Simplified theoretical models of the spine were discussed with particular reference to variables affecting its structural stability in idiopathic scoliosis. These included the geometry, material properties, rate of growth and external loading of the adolescent vertebral column.

TOTAL HIP ARTHROPLASTY IN PREVIOUSLY INFECTED HIP

Hans A. Dahl
Ullevål Hospital
Oslo

Material: Twelve cases of previously infected hips were operated on in one stage, four in two stages, with insertion of a new Charnley-Müller prosthesis fixed with Palamos-Gara mycin-cement.

Seven cases had a total hip arthroplasty, three cases a cup arthroplasty, and two cases a nailed fracture of the neck of the femur

Staphylococcus aureus was cultured in six hips and in four active infection was present. In six hips a definite clinical infection was or had been present, but bacteriological examination was negative.

Postoperatively immediate weightbearing was allowed and systemic antibiotic medication was continued for 2 months.

Results One patient died 3 weeks after the

second stage of severe haemorrhage from stress ulcer, and severe heart infarction.

In 11 cases primary healing occurred and there was no recurrence of infection during the observation time (3 months to 2 years). All patients had a pain free hip and good stability.

Conclusion It seems advisable to replace an infected hip prosthesis and an infected fracture of the neck of the femur with a new prosthesis fixed by Palamos Garamycin® cement and combine this with prolonged antibiotic medication postoperatively.

Oslo, November 20th, 1976

CONGENITAL ELEVATION OF THE SCAPULA

Rolf Daus

Vestfold Central Hospital

Tonsberg

One case operated according to J. W. Wood ward with a good result is reported.

CONGENITAL RADIAL CLUB HAND

Rolf Daus

Vestfold Central Hospital

Tonsberg

A preliminary report is given of a case showing no anomaly of the radius which was treated conservatively for the first year.

MONTeggia FRACTURES IN CHILDREN

For Leif Flørenes

Vestfold Central Hospital

Tonsberg

Three cases are reported. It is asserted that the Monteggia fracture occurs more frequently

in children than is commonly supposed. The surgeon's responsibility to discover the dislocated head of the radius is stressed, because this is often missed by the radiologist.

GALEAZZI FRACTURES

Einar Wollebæk

Vestfold Central Hospital

Tonsberg

This is an isolated overlapping fracture involving the distal two thirds of the radius with an associated disruption of the distal radio ulnar joint. Four cases treated with osteosynthesis are reported.

Oslo, December 18th, 1976

DOG BITE

Arve Smø

Akershus Central Hospital

Nordbyhagen

Out of eleven patients admitted for severe dog bites five were less than 10 years old. Six were wounded in the face, one in the face and hand and four in the upper extremities only. Nine were admitted without delay. Two instances of infection were observed in seven patients who had their wounds revised and sutured out of two only sutured one became infected. Two were admitted late with infected wounds. Of the five patients with wound in

section three were diabetics and in one case no antibiotics had been administered. In two instances late complications occurred. Partial facial nerve palsy persisted in one case, and osteomyelitis necessitated amputation of a finger in the other.

BELOW KNEE AMPUTATION FOR ISCHAEMIC VASCULAR DISEASE

Arve Smø & Gunnar Følterd

Akershus Central Hospital

Nordbyhagen

In the period 1971 to 1975 127 patients were treated with major amputations of the leg for

strain There was no difference between the age groups above and below 60 years as regards average ultimate stress Ultimate strain decreased significantly with increasing age This indicates that cortical bone in young individuals tolerates greater deformation before fracture than bone in older persons

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Oslo

A retrospective comparative study of 107 patients treated with McLaughlin's plate and nail and 104 with Küntschers intramedullary nail for peritrochanteric fractures is reported Mean hospital stay was 341 and 205 days respectively ($P < 0.001$) the mortality within 3 weeks after operation 84 and 77 per cent The mean duration of the anaesthesia was 111 and 81 minutes respectively ($P < 0.001$) the mean operating time 67 and 38 minutes ($P < 0.001$) Patients treated with McLaughlin's method needed significantly more blood transfusions than those who had Küntschers nail Consolidation of the fracture occurred within 8 weeks in 68.6 and 87 per cent ($P < 0.01$) of the patients respectively whereas healing periods exceeded 12 weeks in 20 and 29 per cent respectively Penetration of the nail through the head/neck of the femur occurred most often in the patients with intramedullary nailing Complications which severely affected the patients during the healing period or influenced the final result occurred in 22.5 and 16.7 per cent respectively Pain and stiffness of the hip

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A HISTOLOGICAL DEMONSTRATION OF NERVES IN SUBCHONDRAL BONE

INGE REIMANN & S. BACH CHRISTENSEN

Rigshospitalet Department of Orthopaedic Surgery Copenhagen Denmark

Several different staining procedures were carried out on decalcified histological sections from human femoral heads to demonstrate the nerves in subchondral bone. The femoral heads were obtained at surgery from patients with fractures of the femoral neck or osteoarthritic hip joints. The Bodian technique was found to be the most suitable. Serial sections were used in order to disclose the various sources of error. It was not possible to demonstrate nerves in the bone matrix but they were easily seen in the subchondral bone marrow often related to the vessels. A comparison of the fracture and osteoarthritic cases revealed an obvious difference: more nerves were seen in osteoarthritis. The method described is considered suitable for further study of the nerves in osteoarthritic femoral heads.

Key words: innervation, subchondral bone, osteoarthritis.

Accepted 3.11.77

Relatively few articles have been published in recent literature, about the nerve supply of bone and textbooks of histology hardly mention the subject. This is probably due to the difficulties encountered in working out a reliable technique. The presence of nerves in bone has been demonstrated in the periost in the endosteum of the medullary trabeculae and in the bone marrow, by light microscopy (Sherman 1963, Leeson & Leeson 1970, Miller & McCuskey 1973).

The fact that nerves also occur in the Haversian canals has been shown by electron microscopy (Milgram & Robinson 1965) but it is still a matter of discussion whether or not nerve fibres are present in the bone matrix. Thus, Sherman (1963), Miller & Kasahara (1963), Milgram & Robinson (1965) and Cooper

(1968) were unable to confirm the observations of De Castro (1930) and Hurrell (1937). De Castro described nerve fibres in growing bone in cats, often closely related to the osteocytes, and Hurrell demonstrated nerve fibres in the bone matrix of a fully grown cat. There have been no similar observations in human bone.

The purpose of the present study was to determine whether or not nerves have al-

though it is still not fully elucidated how the nerves end in bone.

This work is an attempt to find a suitable technique for demonstrating nerves in subchondral bone in human femoral heads and to describe some preliminary findings in osteoarthritic femoral heads.

ischaemic gangrene, 58 above- and 69 below-knee. The trend has been towards below-knee amputations. In 1971 above-knee amputations amounted to 82 per cent; in 1975 this figure was 18 per cent.

The age was between 60 and 90 years, 32 were diabetics. "The sagittal flap technique" was used in 59 patients; in 10 the conventional long posterior, short anterior flap technique. Post-operative mortality was 9 per cent, and necrosis and infection occurred in 37 per cent. Re-amputation at higher levels was necessary in 6 per cent of the diabetics, and in 37 per cent of those with simple atherosclerosis.

In 36 patients rehabilitation with prosthesis was considered possible, but only 23 were able to use their prosthesis with benefit.

At present below-knee amputation is used as a standard procedure, except in patients where the gangrene extends to a high level on the lower leg.

SLIPPING RIB SYNDROME

Jørund Asle Holme
Akershus Central Hospital
Nordbyhagen

This syndrome is due to displacement of the anterior end of the anterior cartilages of the eighth, ninth or tenth ribs because of loosening of their fibrous attachments.

Attacks of painful sensations localized to the

costal arch, always preceded by a movement involving the muscles of this region, are the usual complaints. The symptoms are often misinterpreted and thought to be caused by a hernia since the deformity which develops is reducible.

Three female patients with symptoms lasting from 1 to 5 years were operated with resection of the rib cartilage. All were improved.

ONE HUNDRED ASIF-PLATED FRACTURES OF THE FEMORAL SHAFT

Rolf Grøntvedt & Thorleif Wilhelmsen
Akershus Central Hospital
Nordbyhagen

One hundred femoral shaft fractures, 29 comminuted and 12 open, were treated with the lateral ASIF plate.

Road traffic accidents caused the fracture in 68 patients of whom 28 were car occupants and 26 motorcycle riders. Serious accompanying injuries were frequent, mainly head injuries and various fractures. Three had rupture of the femoral artery.

Two elderly patients died from cardiovascular diseases. Osteomyelitis developed in two, non-union in two healed after reoperation. Fat embolism was not seen in 17 patients who were operated upon a few hours after admission, but occurred in 5 patients primarily treated with skeletal traction for 1 week.

Figure 2 Osteocyte lacuna and canaliculi stained by Bodian. Canaliculi are seen with a double outline and a non coloured one in the centre. This can only be demonstrated by using high magnification and focussing (Bodian orig magnification $\times 1000$)



Figure 3 Subchondral bone and bone marrow from a femoral head from a patient with fracture of the femoral neck (trans section of a small nerve (arrow) in association with vessels (haematoxylin eosin orig magnification $\times 100$)



to cross the lamellae it was necessary to study serial sections in order to find whether the lines were present in more than one of the serial sections (Figure 1 A and B).

Staining located to the endost osteochondral junction and tidemark was never interpreted as nerves. Finally Sharpey's fibres which cross the lamellae should be mentioned but the acid used for decalcification impairs the colour as the fibres consist mainly of collagen.

RESULTS

Histological sections from the cases with fracture of the femoral neck. After elim-

ination of the above mentioned sources of error, it was not possible to demonstrate nerve fibres in the bone matrix by the Bodian method. However, in the bone marrow, nerves were easily demonstrated, usually closely associated with the vessels. Whereas the myelin sheath staining gave negative results, staining with haematoxylin eosin and van Gieson showed some cross sections of nerves in the marrow related to the vessels (Figure 3).

Histological sections from osteoarthritic femoral heads. It was also not possible to demonstrate nerve fibres in the bone



Figure 1 A Subchondral bone from osteoarthritic femoral head illustrating staining of cement lines. Due to osteoarthritic alterations the arrangement of lamellae differ from that seen in normal bone (Bodian orig magnification $\times 100$) B A serial section from the same sample at a distance of 6μ . The cement lines are easily recognized

MATERIAL AND METHODS

Twelve femoral heads were obtained from patients at the time of arthroplastic replacement after fracture of the femoral neck (two control material) or osteoarthritis (ten). Immediately after operation the specimens were preserved in 10 per cent buffered formaline phosphate. Equal slices 10 mm thick were obtained from each head with a hand saw. The slices included the circumference of the head with articular cartilage and subchondral bone from both weight bearing and non weightbearing areas. After decalcification in 10 per cent formic acid and embedding in paraffin the samples were cut in serial sections at 6μ and subsequently stained.

The Bodian method was used for axon staining and staining of the myelin sheaths was performed according to the method of Mahon and Weill. In addition staining with haematoxylin-eosin and \vee Gieson was performed.

The final evaluation was based on the histological sections stained with Bodian's method. In the present work a modification used routinely at the Laboratory of Paediatric Pathology, Rigshospitalet was used. It is as follows:

- 1 Deparaffinize and hydrate with distilled water
- 2 Place slides in protargol solution 1 per cent and add 6 g of clean copper shot per 100 ml of solution. Let stand at 37°C for 24 hours
- 3 Rinse in distilled water, three changes

- 4 Staining solution for approximately 5 minutes: 4 ml silver nitrate (10 per cent) with supersaturated sodium sulphite until clear. Add 3 ml of this solution to 300 ml gum arabic and shake for 5 minutes then add 30 ml 2 per cent hydroquinone
- 5 Rinse in distilled water three changes
- 6 Tone in gold chloride solution 1 per cent with addition of three drops glacial acetic acid per 100 ml solution. Tone for 5 minutes
- 7 Rinse in distilled water three changes
- 8 Develop in oxalic acid (2 per cent) approximately 5 minutes
- 9 Rinse in distilled water three changes
- 10 Sodium thiosulphate (5 per cent) for 5 minutes
- 11 Rinse in distilled water, dehydrate in alcohol and clear in xylene

It was necessary to work out methods which would eliminate the various sources of error as structures other than nerve fibres in the bone become stained by the Bodian method (Figures 1 and 2) e.g. both canaliculi and lacunae become stained black. In doubtful cases where canaliculi resembled nerves it was possible to show by light microscopy (magnification $\times 1000$) that the black colour in canaliculi appears as a lining and consequently the canaliculi are seen with a double outline enclosing a non coloured zone (Figure 2). The cement lines between the different systems of lamellae were also stained by Bodian's method. When a black line appeared



Fig. 1. Nerve fibers in the bone marrow (arrow). (Orig. magnification $\times 100$)
 D) Same as C (Orig. magnification $\times 100$)

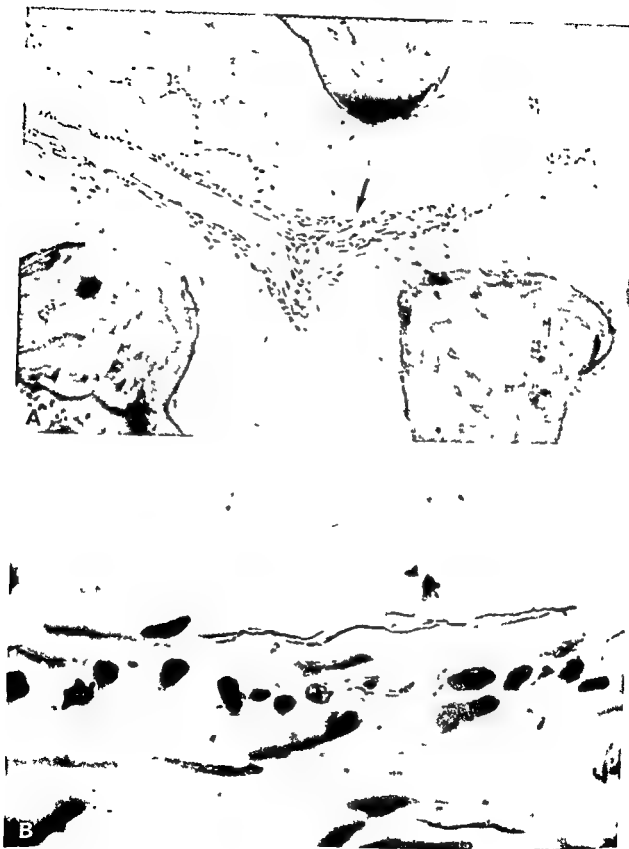


Figure 4 Subchondral bone from osteoarthritic femoral head A Longitudinal section of a nerve fibre (arrow) related to an arteriole (Bodian orig magnification $\times 100$) B Same as A (Orig



Figure 6 A Subchondral bone (cartilage absent) from osteoarthritic femoral head. Nerve (arrow) is seen located in a cyst with granular contents (Bodian or gold magnification $\times 100$) B same as A (Or gold magnification $\times 1000$)

matrix are stained black in the same way as the nerves (Green et al 1970). This applies to the osteocyte lacunae and particularly to canaliculi as they are lined with sulphated mucopolysaccharide (Ham 1969). According to Leeson & Leeson (1970) the black stained cement lines also contain mucopolysaccharide. The authors confirm this by staining the sections with Alcian Blue; an obvious green colour was then seen located to the osteocyte lacunae and to a minor degree to the canaliculi and a diffuse green glow was seen in some sections of the bone matrix contrasting with the red colour of the bone.

According to Bodian (1937) treatment with acid should impair the colour of

collagen and thus eliminate structures such as Sharpey's fibres. This was confirmed by staining sub-synovial fibrous tissue with Bodian after treatment with 5 per cent acetic acid.

Decalcification has been discussed Hurrell (1937) who used 6 per cent nitric acid to decalcify mentioned that it was necessary to use alum to prevent swelling of the matrix caused by the acid. This on the other hand interferes with the impregnation of the soft tissue. Rowles & Brain (1959) used 10 per cent formic acid to decalcify sections of teeth before staining nerve fibres with silver and Gough (1970) stated that 10 per cent formic acid could be used to decalcify before silver impregnation.



Figure 5 A Subchondral bone and cartilage from osteoarthritic femoral head. Vessels penetrate from the subchondral marrow. Solitary axon is seen accompanying the vessels (arrow) (Bodian org magnification $\times 100$) B Same as A (Orig magnification $\times 1000$)

matrix in these sections by Bodian's method. However, several nerve fibres, in longitudinal as well as cross sections, were seen in the bone marrow subchondrally where an abundance of vessels were also found (Figure 4 A, B, C, & D). As nerves were also demonstrated in sections with a proliferation of vessels into the calcified layer of articular cartilage (Figure 5 A & B), as well as in the subchondral granulation tissue (Figure 6 A & B) it was evident that there were more nerves in the osteoarthritic femoral heads than in the control cases.

The other staining methods gave results similar to those described for the sections from the fracture cases.

DISCUSSION

The distribution, character and ending of nerves in bone have not been fully elucidated.

In the present work the method of Bodian (1936, 1937)—an accepted axon staining method—was chosen as almost all nerve fibres in bone are unmyelinated (Cooper 1968) and, furthermore, as myelin sheath staining in our experience produced only negative results.

In analysing the decalcified sections of bone stained with Bodian's method, many considerations were taken into account concerning the method and results. Bodian staining is not specific for nerve fibres as many other structures in the bone

ARTERIAL EMBOLIZATION FOR RADICAL TUMOR RESECTION

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Two contemporary measures, selective transarterial embolization (Almgard et al 1973) and controlled hypotensive anesthesia (Davis et al 1974), have been combined in an effort to reduce the risk of operative bleeding in a case of massive bone and muscle resection of a highly vascular carcinoma lesion in the proximal third of the femur. This approach may be helpful in such cases.

Key words: bone neoplasia, resection, controlled hypotension, selective arterial embolization.

Accepted 25.11.77

Severe hemorrhage during radical operations for excision of malignant lesions remains a potential, serious risk. A case is reported in which an effort to reduce this risk was made by combining preoperative transarterial embolization and intraoperative-induced hypotensive anesthesia. The operation involved resection of the proximal half of the femur with surrounding muscles and insertion of a proximal femoral replacement total hip implant.

CASE REPORT

A 45-year-old man was admitted for treatment of a metastatic lesion of the left proximal femur. Eight months previously he began having intermittent aching in his left knee. Three months later, x-ray examination revealed an osteolytic lesion of the left proximal femur. No primary site of the tumor was identified. Blood count was impressive. Two units of blood had to be given and the small biopsy wound

had to be packed in order to obtain hemostasis. Pathological evaluation of the specimen revealed "metastatic carcinoma—primary unknown". Mithramycin was begun and 3000 rad of super-voltage Cobalt 60 radiation were given. Two months later he was placed in a spica cast because of increasing pain in his left hip, and he was begun on vincristin sulfate¹, Cyclophosphamide² and 5-fluorouracil³. When admitted to the Massachusetts General Hospital pain in his hip was intolerable despite being in the spica cast. X-ray films revealed substantial extension of the tumor with two pathologic fractures, one in the femoral neck and another in the proximal femoral shaft (Figure 1).

Again a primary focus could not be identified, nor other secondary lesions. It was decided to resect the proximal femur and surrounding soft tissues *en bloc* and to perform replacement arthroplasty with a custom Mueller proximal femoral replacement prosthesis. Prophylactic

- ¹ Mithramycin, Pfizer, Inc., New York, New York.
- ² Oncovin, Eli Lilly and Company, Indianapolis, Indiana.
- ³ Cytosan, Mead Johnson Laboratories, Evansville, Indiana.
- ⁴ Fluorouracil, Roche Laboratories, Nutley, New Jersey.

In the present study, 10 per cent formic acid was also used. As in recent years undecalcified sections have been used routinely in many laboratories, sections were also prepared for Bodian staining after they had been embedded in methyl methacrylate, however, as details in the bone matrix were not so distinct, we preferred the decalcified sections.

Only subchondral bone from human femoral heads has been examined in this work. In the sections from "normal" bone it was not possible, after eliminating several sources of error, to demonstrate nerve fibres in the bone matrix, but only in the marrow. In sections from osteoarthritic femoral heads it was obvious that there was an increased number of nerves, as they were related to the increased amount of vessels subchondrally in the bone marrow and in the granulation tissue.

From this preliminary work it may be concluded that there seems to be a greater number of nerves in osteoarthritic subchondral bone than in normal bone, and this is probably by analogy with the increased vascularization. The subject may be used for further studies, as the various causes of pain in osteoarthritis are still not quite elucidated.

ACKNOWLEDGEMENTS

The authors wish to thank Ms K E Sonderlev for careful technical assistance in the preparation of the histological sections used in this study.

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REFERENCES

- Bodian, D (1936) A new method for staining nerve fibers and nerve endings in mounted paraffin section *Anat Rec* 65 89-97
- Bodian, D (1937) The staining of paraffin sections of nervous tissue with activated protargol. The role of fixatives *Anat Rec* 69 153-162
- Cooper, R (1968) Nerves in cortical bone *Science* 160 327-328
- De Castro I (1930) Quelques observations sur l'intervention du système nerveux autonome dans l'ossification. Innervation du tissu osseux et de la moelle osseuse *Trav Lab Rech Biol de l'Univ de Madrid* 215-244
- Gough N G (1970) The staining of nerves in serial sections *J Anat (Lond)* 106 437-449
- Green W T, Garland N M, Fanes H E & Sokoloff, I (1970) Microradiographic study of the calcified layer of articular cartilage *Arch Path* 90 151-158
- Ham A W (1969) *Histology* 6th ed p 358 Pitman Medical Publishing Co, Ltd London
- Hurrell D J (1937) The nerve supply of bone *J Anat (Lond)* 72 54-61
- Ieesson T S & Ieesson C R (1970) *Histology* 2nd ed pp 121-123 W B Saunders Co Philadelphia London Toronto
- Milgram, J & Robinson, R A (1965) An electronmicroscopic demonstration of unmyelinated nerves in Haversian canals of the adult dog *Bull Johns Hopl Hosp* 117 163-173
- Miller M I & McCuskey R S (1973) Innervation of bone marrow in the rabbit *Scand J Haemat* 10 17-23
- Miller M R & Kasahara M (1963) Observations on the innervation of human long bones *Anat Rec* 145 12-23
- Rowles S I & Brain I B (1959) An improved silver method for staining nerve fibres in decalcified sections of teeth *Arch oral Biol* 2 64-68
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Accepted 25 iii 72

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Again a primary focus could not be identified nor other secondary lesions. It was decided to resect the proximal femur and surrounding soft tissues *en bloc* and to perform replacement arthroplasty with a custom Mueller proximal femoral replacement prosthesis. Prophylactic

CASE REPORT

A 55-year-old man was admitted for treatment of a metastatic lesion of the left proximal femur. Eight months previously he began having intermittent aching in his left knee. Three months later x-ray examination revealed an osteolytic lesion of the left proximal femur. A primary lesion could be identified. Open biopsy of the femoral lesion was performed at another hospital. During this relatively minor surgery blood loss was impressive. Two units of blood had to be given and the small biopsy wound

¹ Mithracin Pfizer Inc., New York, New York.
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REFERENCES

- Bodian, D (1936) A new method for staining nerve fibers and nerve endings in mounted paraffin section *Anat Rec* 65 89-97
- Bodian D (1937) The staining of paraffin sections of nervous tissue with activated protargol. The role of fixatives *Anat Rec* 69 153-162
- Cooper R (1968) Nerves in cortical bone *Science* 160 327-328
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- Gough N G (1970) The staining of nerves in serial sections *J Anat (Lond)* 106 437-449
- Green W T, Garland N M, Eanes D F & Solovoff, I (1970) Microradiographic study of the calcified layer of articular cartilage *Arch Path* 90 151-158
- Ham A W (1969) *Histology* 6th ed p 388 Pitman Medical Publishing Co Ltd London
- Hurrell D J (1937) The nerve supply of bone *J Anat (Lond)* 72 54-61
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- Milgram J & Robinson R A (1960) An electronmicroscopic demonstration of unmyelinated nerves in Haversian canals of the adult dog *Bull Johns Hopk Hosp* 117 163-173
- Miller, M L & McCuskey R S (1973) Innervation of bone marrow in the rabbit *Scand J Haemat* 10 17-23
- Miller M R & Kasahara M (1963) Observations on the innervation of human long bones *Anat Rec* 145 12-23
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Figure 3 Anteroposterior roentgenogram of the left hip area showing the proximal femoral replacement total hip arthroplasty

lications of the angiography the embolization

was
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■ "Well differentiated adenocarcinoma probably of gastrointestinal origin" No primary lesion was found Thirty six months after his operation he was ambulatory with one cane had no pain and had returned to work The lesion had not recurred

DISCUSSION

Three factors contributed to the reduced blood loss in the excision of this highly vascular tumor namely induced hypotensive anesthesia selective arterial embolization and *en bloc* excision A prospective controlled series is needed to prove a significant reduction had oc-

curred and to establish which of the three factors was most valuable However, the experience during the biopsy in this case and experiences with other similar replacement operations with induced hypotensive anesthesia and preoperative selective arterial embolization suggest strongly to the authors that these measures were helpful

Stener (1962) described the method of temporary arterial occlusion for the purposes of reducing operative bleeding and to lessen the risk of the tumor spreading However, this method of temporary occlusion requires an abdominal incision in addition to the large incision needed in this case to remove the tumor Since preoperative arteriography was necessary for evaluation of the vascularity of the tumor, little extra time or risk was involved in arterial embolization while the catheter was in place for this study Arterial embolization preoperatively has been used in reducing the circulation to malignant tumors in urologic surgery (Almgard et al 1973)

REFERENCES

- Almgard L E Fernstrom I Haverling M & Ijungquist A (1973) Treatment of renal adenocarcinoma by embolic occlusion of the renal circulation *Brit J Urol* 45 474-479
- Coventry M B Nolan D R & Beckenbaugh R M (1973) "Delayed prophylactic anticoagulation A study of results and complications in 2012 total hip arthroplasties" *J Bone Jt Surg* 55-A 1487-1492
- Davis N J Jennings J J & Harris W H (1974) Induced hypotensive anesthesia for total hip replacement *Clin Orthop* 101 93-98
- Ring F J, Waltman A C Athanasoulis C A Smith J C & Baum S (1974) Angiography in pelvic trauma *Surg Gynec Obstet* 139 375-380
- Stener Bertil (1962) Reduction of operative bleeding in the thigh by temporary occlusion of the common iliac artery *Acta chir scand* 123 360-364



Figure 1 Arteriogram of the left hip region showing marled vascularity of the metastatic lesion



Figure 2 Repeat arteriogram immediately after introduction of Gelfoam clot showing obstruction of the major arteries going to the tumor. The extensive destruction of bone and the two pathologic fractures in the subtrochanteric region can be seen on this film

anticoagulation with warfarin⁵ was instituted because of high thromboembolic risks following total hip replacement surgery (THR) (Coventry et al 1973) because his operation was to be more extensive than the usual THR and because he was to be in bed for 11 weeks postoperatively.

A catheter was introduced via the opposite femoral artery to study the vascularity of the tumor, the major feeding vessels and the collateral circulation. Arteriography of the left common iliac external and internal iliac arteries demonstrated that the major supplying vessels arose from external iliac. Little collateral circulation was present. At the same time absorbable gelatin sponge⁶ fragments were introduced transarterially as emboli to occlude the major feeding vessel (Figure 2). In order to

avoid an increase in collateral circulation the surgery was performed within 24 hours.

The following day under halothane⁷ general anesthesia controlled hypotension was induced with pentolinum tartrate⁸. The tumor was excised en bloc and the custom design total hip replacement was performed (Figure 3). The excised mass was 20×11×7 cm. Total measured intraoperative blood loss was 2500 cm³. One unit of blood was given preoperatively because his hematocrit was 29 per cent. He received six units the day of surgery and one unit of blood 9 days postoperatively. Total blood replacement during this admission was eight units.

The postoperative course was benign. No com-

⁵ Coumadin Indo Laboratories, Garden City, New York

⁶ Gelfoam The Upjohn Company, Kalamazoo, Michigan

⁷ Fluothane, Avers Laboratories, New York, New York

⁸ Ansolylen Wyeth Laboratories, Philadelphia, Pennsylvania

Control material

Studies of fracture incidence in a normal population have been carried out earlier in the city of Malmö (210 000 inhabitants), and have included fractures of the forearm (radius) (Allfram & Bajer 1962), cervical and trochanteric fractures of the femur (Allfram 1964), ankle fractures (Nilsson 1969) and fractures of the upper end of the humerus (Hörac & Nilsson 1975). In this investigation we have compared

in these bones in a normal population

*Statistical methods**

Using the hypothesis that the group of patients under study are exposed to fractures at no higher than the normal rates, the expected number of fractures of each type in each age and sex group during the period of study can be computed as the product of the normal group rate by the number of patients in the group by the number of years under study. A significantly higher number of observed fractures in any group indicates that this group is exposed to fractures at a higher rate than the normal group.

To determine what should be meant by a significantly higher number of observed fractures the instances of fracture are considered as occurring randomly in time and independently of each other. This somewhat idealized model immediately leads to the consequence that the number of observed fractures in any one group is Poisson-distributed with the mean equal to the

real levels of significance can readily be computed. Also because of the additive property of Poisson variables (i.e. the sum of independent Poisson variables is itself Poisson distributed, with the mean equal to the sum of the means of the variables) both the expected and the observed numbers in any set of subgroups can be added to form a larger group and the same type of test can then be used for this new group.

The large number of single tests allowed by this material (in the order of 100) makes it necessary to consider the problem of spurious significance. A series of 100 independent tests, each performed on the 1% per cent level will maintain on the average five spurious significances and so forth. To keep down the risk of

spurious significances, a much lower level has to be used in each test. To make the risk of one spurious significance 1 per cent, each test has to be performed on the 0.01 per cent level of significance.

RESULTS

Fifty-three epileptics had no fractures during the 7-year period. Thirty-four had 76 fractures. Of these, 26 were with certainty related to epileptic seizures and 44 probably not related to seizure. Table 1 shows the type of fracture.

Of the fractures, 35 in number, for which we have incidence totals from the Malmö surveys, 22 in 17 epileptics were probably not related to seizures (Table 1). These we have studied further. The mean age for the 17 epileptics was 61 ± 8 years.

In Tables 2-6 a comparison is made between the expected number of frac-

Table 1 Seventy fractures in 34 epileptic patients

Site of fracture	Men	Women
Humerus neck	2 (1)	2 (2)
Radius	4 (1)	3 (1)
Femur neck	1	3
Femur trochanter	4 (3)	4
Ankle (malleolus)	5 (2)	11 (3)
Clavicle	3 (3)	1
Humerus supracondyle	0	1 (1)
Olecranon	0	1
Hand	2 (2)	3 (1)
Cervicthrae	0	2 (1)
Pelvis	1 (1)	3
Femur supracondyle	0	4
Tibia-condyle	0	6 (1)
Tibia and fibula	1	1
Foot	1 (1)	5 (2)
Total	24 (14)	46 (32)
Total	70 (26)	

The numbers within parentheses indicate fractures which have occurred during epileptic seizures.

*Statistical calculations were performed by Per Overbeck, Department of Mathematical Statistics, University of Lund.

INCIDENCE OF FRACTURE IN EPILEPTICS

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In 87 epileptics on diphenylhydantoin, the occurrence of non seizure related fractures, over a period of 7 years was six times greater than that found in the normal population. The significant increase in fracture incidence was found to lie within the 45-64 age group indicating that epileptics are not only more prone to fractures but also have an earlier fracture debut.

Key words: diphenylhydantoin, epilepsy, fracture, osteomalacia

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A great number of studies in recent years have shown that 25 per cent of all patients undergoing antiepileptic treatment develop osteomalacia. This finding is based on blood chemistry tests and on X-ray examinations (Dent et al 1970, Hunter et al 1971, Borgstedt et al 1972, Christiansen et al 1972, Kraft et al 1974, Livingstone & Pauli 1974, Kruse 1975). A high incidence of fracture in epileptic patients can be expected because of the nature of the illness (Vasconcelos 1973), but no investigation of this subject can be found in the literature. The aim of the present study, which is part of a larger survey, has been to compare the incidence of fractures not related to seizures in 87 epileptics, over a period of 7 years, with the expected incidence in a normal population.

MATERIAL AND METHODS

Proband material

The material comprises 87 epileptics, 49 women and 38 men. The mean age for the

women was 56 ± 12 years and for the men 55 ± 12 years. Most of the epileptics have suffered from the disease since childhood and all have been on anticonvulsant therapy for more than 10 years: in most cases on diphenylhydantoin (200-500 mg average dose 350 mg) and Phenemal (100 mg). More recently Myslepin has been prescribed for a few patients. Serum concentration determination of diphenylhydantoin has not been carried out routinely. Most of the epileptics are debilitated to a minor degree but have had steady employment and lived in their own apartments in a home for epileptics (Fogdarodshemmet). None of them have been on general steroid therapy. Two have diabetes mellitus and one has rheumatoid arthritis but these three are not included in the fracture group.

In cases of serious skeletal damage examinations have been carried out in one of three X-ray units. We have gone through the archives in all three units for the period January 1969 through December 1975. During this time all of the patients in the present study lived in the above mentioned home. This has made it possible for us to register the majority of the more serious fractures. At the same time with the help of the personnel at the home and by studying the referrals for X-ray examination we have been able to differentiate the fractures which have occurred in connection with epileptic seizures.

Table 5 Observed frequency of trochanteric fractures of the femur (*Fract troch fem*) in epileptic patients as compared with expected frequency in the normal population

Age		20-44 years	45-54 years	55-64 years	65-74 years	75-79 years	Total
Men	Obs freq	0	0	0	1	0	1
	Exp freq	0.0019	0.0037	0.0178	0.0506	0	$P > 0.05$ 0.0840
Women	Obs freq	0	0	3	1	0	4
	Exp freq	0.0007	0.0049	0.0391	0.0999	0.0461	$P < 0.0001^{***}$ 0.1807
Total	Obs freq	0	0	3	2	0	5
	Exp freq	0.0026	0.0086	0.0569	0.1505	0.0461	$P < 0.0001^{***}$ 0.2647

Table 6 Observed frequency of ankle fractures (*Fract mall pedis*) in epileptic patients as compared with expected frequency in the normal population

Age		20-44 years	45-54 years	55-64 years	65-74 years	75-79 years	Total
Men	Obs freq	0	1	1	1	0	3
	Exp freq	0.0707	0.0420	0.1001	0.0601	0	$P < 0.01^*$ 0.2779
Women	Obs freq	0	0	1	0	1	2
	Exp freq	0.0113	0.0391	0.1764	0.1134	0.0056	$P > 0.05$ 0.3708
Total	Obs freq	0	1	2	1	1	5
	Exp freq	0.1120	0.0811	0.2765	0.1735	0.0056	$P < 0.001^{**}$ 0.6537

tures in 87 persons over a period of 7 years and the observed number in the epileptic group. The fractures are classified according to type. This comparison is also shown for the totals graphically in Figure 1.

In adding together the totals for the various types (Tables 2-6), we find that the significant increase in the occurrence of fractures appears in the 45-54 and 55-64 age groups (Figure 1). The ex-

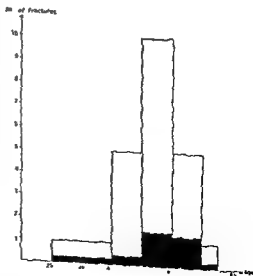


Figure 1 Observed frequency of fractures not related to seizures in 87 epileptics (open columns) as compared with frequency in the normal population (filled columns) over a 7 year period.

Table 2 Observed frequency of fractures of the upper end of the humerus (*Fract colli humeri*) in epileptic patients as compared with expected frequency in the normal population

Age		25-44 years	45-54 years	55-64 years	65-74 years	75-79 years	Total
Men	Obs freq	0	1	0	0	0	1
	Exp freq	0.0147	0.0189	0.0770	0.0910	0	$P > 0.05$ 0.2016
Women	Obs freq	0	0	0	0	0	0
	Exp freq	0.0210	0.0406	0.2016	0.1848	0.0392	$P > 0.05$ 0.4312
Total	Obs freq	0	1	0	0	0	1
	Exp freq	0.0357	0.0595	0.2786	0.2758	0.0392	$P > 0.05$ 0.6999

Table 3 Observed frequency of forearm fractures (*Fract radii*) in epileptic patients as compared with expected frequency in the normal population

Age		25-44 years	45-54 years	55-64 years	65-74 years	75-79 years	Total
Men	Obs freq	0	2	0	1	0	3
	Exp freq	0.0266	0.0112	0.0567	0.0385	0	$P < 0.001$ 0.1330
Women	Obs freq	0	0	2	0	0	2
	Exp freq	0.0385	0.1120	0.6970	0.5103	0.0799	$P > 0.05$ 1.4336
Total	Obs freq	0	2	2	1	0	5
	Exp freq	0.0651	0.1232	0.7497	0.5488	0.0789	$P > 0.05$ 1.5666

Table 4 Observed frequency of cervical fractures of the femur (*Fract colli fem*) in epileptic patients as compared with expected frequency in the normal population

Age		25-44 years	45-54 years	55-64 years	65-74 years	75-79 years	Total
Men	Obs freq	1	0	0	0	0	1
	Exp freq	0.0032	0.0039	0.0356	0.0158	0	$P > 0.05$ 0.1085
Women	Obs freq	0	1	3	1	0	5
	Exp freq	0.0028	0.0125	0.1058	0.1959	0.0701	$P < 0.0001$ 0.3871
Total	Obs freq	1	1	3	1	0	6
	Exp freq	0.0060	0.0164	0.1414	0.2117	0.0701	$P < 0.0001$ 0.4956

REFERENCES

- Alfaram P A (1964) An epidemiologic study of cervical and trochanteric fractures of the femur in an urban population *Acta orthop scand* Suppl 65
- Alfaram P A & Bauer G C H (1962) Epidemiology of fractures of the forearm. A biomechanical investigation of bone strength *J Bone Jt Surg* 44 A 105-114
- Asplid J (1976) Vitamin D resistant rickets *Tidsskr Lægeforen* 96 349-354
- Bergstedt A D, Hirsén M F, Young L W & Forbes G B (1972) Long term administration of antiepileptic drugs and the development of rickets *J Pediatr* 81 9-15
- Blair J E (1974) Vitamin D—An old hormone rediscovered *Scott med J* 19 247-249
- Christiansen C, Kristensen M & Rodbro P (1972) Latent osteomalacia in epileptic patients on anticonvulsants *Brit med J* 3 238-239
- Christiansen C, Rodbro P & Lund M (1973 a) Effect of vitamin D on bone mineral mass in normal subjects and in epileptic patients on anticonvulsants. A controlled therapeutic trial *Brit med J* 3 208-209
- Christiansen C, Rodbro P & Lund M (1973 b) Incidence of anticonvulsant osteomalacia and effect of vitamin D. Controlled therapeutic trial *Brit med J* 4 695-701
- Christiansen C & Rodbro P (1974) Initial and maintenance doses of vitamin D₂ in the treatment of anticonvulsant osteomalacia *Acta neurol scand* 50 631-641
- Christiansen C, Rodbro P & Sjögård O (1975 a) Biochemical status in epileptic patients during treatment with vitamin D *Acta neurol scand* 51 81-86
- Christiansen C, Rodbro P, Munch O & Munch H (1975 b) Actions of vitamin D₂ and D₃ and 25-OH-D₃ in anticonvulsant osteomalacia *Brit med J* 17 363-365
- Dent C F, Richens A, Rowe H J F & Stamp T C B (1970) Osteomalacia with long term anticonvulsant therapy in epilepsy *Brit med J* 4 70-72
- Gharib H & Monoz J M (1974) Endocrine manifestations of diphenylhydantoin therapy *Metabolism* 23 515-524
- Horae J & Nilsson H F R (1975) Epidemiology of fractures of the upper end of the humerus *Clin Orthop* 112 256-263
- Hunter R, Maxwell J D, Stewart D A & Williams R (1971) Altered calcium metabolism in epileptic children on anticonvulsants *Brit med J* 4 202-204
- Kraft D, von Herrath D & Schaefer K (1974) Antikonvulsiva und Vitamin D stoffwechsel *Munch med Wschr* 116 1579-1583
- Kruse R (1975) Osteopathien Kalzium und Vitamin D Stoffwechselstörungen unter anti epileptischer Langzeittherapie *Bibl psychiat neurol (Basel)* 151 114-143
- Latorre H & Henon F M (1974) High dosage intravenous calcium therapy for osteoporosis and osteomalacia in anticonvulsant therapy with hypomobilitization *Pediatrics* 53 100-105
- Livingstone S & Pauli L L (1974) Anticonvulsants and vitamin D metabolism *Develop Med Child Neurol* 16 683-684
- Nilsson B E R (1969) Age and sex incidence of ankle fractures *Acta orthop scand* 40 122-129
- Schaefer K (1974) Aktuelle klinische Probleme der Vitamin D Forschung *Munch med Wschr* 116 1562-1567
- Vasconcelos D (1973) Compression fractures of the vertebrae during major epileptic seizures *Epilepsia (Amst)* 14 323-328

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pected incidence for the age group 45-54 years is 0.3 fractures, whereas the observed incidence is 5.0 ($P < 0.0001^{***}$); the expected incidence for the age group 55-64 years is 1.5 and the observed is 10.0 ($P < 0.0001^{***}$).

The expected fracture incidence for men, for the five fracture types, is 0.8 and the observed incidence is 9.0 ($P < 0.0001^{***}$). The expected incidence for women is 2.9 fractures, while the observed incidence is 13 ($P < 0.0001^{***}$). The consolidated totals show an expected incidence of 3.7 fractures and an observed incidence of 22 ($P < 0.0001^{***}$).

DISCUSSION

Several reports on osteomalacia in epileptic patients have appeared in the literature in recent years and it has been suggested that antiepileptic therapy, especially diphenylhydantoin, is the cause of the skeletal changes and that osteomalacia in epileptics is probably related to a relative deficiency of vitamin D or of its metabolites. Epileptics with osteomalacia have a low urine-calcium value, a high level of alkaline phosphates, and, in 10-20 per cent of cases, a low serum-calcium value. The low serum-calcium rate can in turn possibly cause cramp attacks and antiepileptic therapy can mask this effect (Gharib & Munoz 1974).

Vitamin D₃ (cholecalciferol) can be produced in the skin through the effect of ultra-violet light, or it can be absorbed from the intestinal canal. A first step in the hydroxylation process occurs in the liver, producing 25-hydroxycholecalciferol. This metabolite is probably not active but circulates in the blood. The next hydroxylation process occurs in the kidneys, producing the active metabolite 1,25-dihydroxycholecalciferol. This metabolite affects the mucous membranes of the small intestine, the kidney tubuli and the bone tissue, principally by increasing

the organism's absorption-reabsorption of calcium and phosphorus and also regulates the mineralization of bone tissue. The hydroxylation process is probably affected by diphenylhydantoin, but it is not yet clear if this occurs in the liver or in the kidneys (Boyle 1974; Schaefer 1974; Apold 1976).

Fracture incidence in epileptics is high as expected, because of the nature of the disease (Table 1), but it is possible that antiepileptic therapy with diphenylhydantoin and the resultant osteomalacia cause an increase in frequency. Several reports on material comprising smaller numbers of patients have indicated that treatment with vitamin D can have a beneficial effect on osteomalacia in epileptic patients on diphenylhydantoin (Christiansen et al 1973 a, b; Christiansen & Rodbo 1974; Latorre & Kenny 1974; Christiansen et al 1975 a, b).

In 87 patients on diphenylhydantoin we found a significant increase in the incidence of non-seizure-related fractures in particular cervical and trochanteric fractures of the femur (Tables 4 and 5), and ankle fractures (Table 6), as compared with the expected incidence in a normal population. In the 7-year period the frequency of occurrence of non-seizure-related fractures in the 87 epileptics was six times that in the normal population (nine times for the men and four times for the women) (Tables 2-6).

When the epileptics are grouped according to age, the significant increase in fracture incidence is found within the 45-64 age group (Figure 1). This indicates that epileptics are not only more prone to fractures, but also have an earlier fracture début.

Our present study represents part of a larger survey undertaken to relate fracture-proneness to the morphology and blood chemistry of epileptics in an effort to establish a basis for preventive treatment.

MATERIAL AND METHODS

Consecutive unselected cases of osteoarticular tuberculosis who could provide an aspirable tuberculous material in the form of a tuberculous joint effusion or a cold abscess were included in this study. During preliminary work, a material of diseased osseous tissue granulation tissue and sequestra obtained from patients undergoing direct surgery for diagnostic or therapeutic purposes was also collected. However, this was later excluded from the present report because of frequent mixing with blood and a lack of control of the time interval for collection of the samples. Cases with doubtful diagnosis and with gross secondary infection were also excluded. Thus for the final assessment material from 79 cases was available.

The age of the patients varied between 8 months and 60 years; there were 111 males and 41 females. The disease in all the patients was active and well established. Fourteen patients had tuberculosis of joints (Group I), 13 knee joints and one elbow. Group II consisted of 65 patients who provided material from an abscess in 34 cases and a cold abscess in other parts of the body in 31 cases. One of these patients provided 2 samples from cold abscesses in the arm and thigh. The majority of the patients showed varying degrees of tubercular cachexia and haemoglobin concentration on an average was 10 g per cent.

Administration of drugs and aspiration of material

The patients were weighed and were administered streptomycin sulphate intramuscularly in doses of 25 mg per kg of body weight (not exceeding one g) well away from the site of proposed aspiration. Ethambutol hydrochloride 25 mg per kg of body weight was given by mouth on an empty stomach. The drugs were administered for 2 consecutive days and on the second day 3 hours after the administration blood and tuberculous material were aspirated under aseptic conditions. Special care was taken to avoid mixing of blood with the tuberculous aspirate.

Assay of the drugs

The broth dilution microbiological bioassay technique (Holmar et al 1969) was used for estimating the concentration of streptomycin in serum and the aspirate. For ethambutol a chemical assay technique was employed (Allen & Baker 1965).

Reassessment

After the first investigation the patients were put on the standard triple drug therapy consisting of streptomycin IVI and ethambutol/PAS. Four patients from Group II provided the aspirable material for re-analysis 3 to 5 months after the onset of their treatment.

RESULTS

Observations regarding concentration of drugs in the joint aspirate and serum in Group I are summarised in Table 1, and

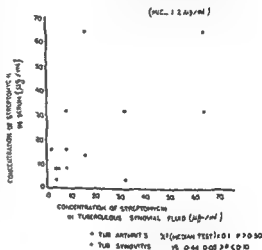


Figure 1 Correlation between the concentration of streptomycin in serum and in tuberculous synovial fluid (Group I)

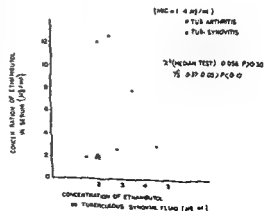


Figure 2 Correlation between the concentration of ethambutol in serum and in tuberculous synovial fluid (Group I)

PENETRATION OF ANTITUBERCULAR DRUGS IN CLINICAL OSTEOARTICULAR TUBERCULAR LESIONS

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In 79 consecutive cases of skeletal tuberculosis the concentration of streptomycin and ethambutol was analysed. The material for analysis was obtained from the diseased joints of 14 patients and from cold abscesses from spinal or osseous lesions in 65 patients. The concentration of the drugs in the serum and in the tuberculous material was measured 3 hours after the systemic administration of the drugs at therapeutic doses. The concentration was expressed as μg per ml of the tuberculous material and the data were subjected to statistical analysis. Streptomycin and ethambutol penetrated freely into the tuberculous joints, their concentration in the cold abscesses, however, was half to one third of the concentration in the serum. There was a wide range of concentrations, however, in the tuberculous joints as well as in the cold abscesses the concentrations were much higher than those considered to have an inhibitory effect on *Mycobacterium tuberculosis* in clinical material.

Key words: antitubercular drugs, osteoarticular tuberculosis, drug penetration, ethambutol, streptomycin.

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It has long been presumed that antitubercular drugs do not reach osteoarticular tuberculous lesions in adequate concentrations, and universal radical excisional surgery has been practised and advocated by many workers to ensure penetration of the drug into skeletal tuberculous lesions. In recent times, however, a few clinical reports, especially from the developing countries, have been published, proving the efficacy of antitubercular drugs. The quality, rapidity, consistency and durability of healing in clinical material led many workers to infer that the drugs were indeed reaching the site of infection (Landberg 1967,

Friedman & Kapur 1973, Medical Research Council 1973, Tuli 1975). To resolve the controversy regarding the power of penetration of antituberculous drugs an experimental study was reported in 1974 by the senior author proving the easy accessibility of the experimental osseous tuberculous lesions to streptomycin (Tuli et al 1974). The present study was undertaken to determine the concentration of streptomycin and ethambutol in clinical osteoarticular tuberculous lesions.

Concentration of streptomycin in serum

In Group I and Group II the range of concentration was 3.5–64.0 µg per ml. Statistically the range in both groups was almost equal, the average concentration, however, was 23.34 µg per ml in Group I and 13.47 µg per ml in Group II. This difference between the two groups, though statistically insignificant (median = 8, $x^2 = 2.41$, $P > 0.10$) may be explained on the basis of the relatively better general condition of the patients in Group I.

Concentration of streptomycin in joint aspirate

The concentration in the joint aspirate was observed to be almost equal to that of the serum (median = 16, $x^2 = 0.1$, $P > 0.50$) meaning that streptomycin flows freely from the serum into the joint without any functioning barrier.

Concentration of streptomycin in cold abscess

The range of concentration in 66 samples was 0.5–32.0 µg per ml, with an average of 6.03 µg per ml and median concentration of 4.0 µg per ml. It was observed that there was a significant difference between the serum and pus concentrations (median = 8, $x^2 = 5.23$, $P < 0.05$). Spearman's rank correlation coefficient ($r_s = 0.72$, $P < 0.001$) suggested a strong correlation, i.e. with higher serum concentration there was a corresponding rise in the concentration in the abscess. In general the concentration in the cold abscess was one third of that in the serum.

Concentration of ethambutol in serum

The concentration in Group I ranged between 1.9–12.5 µg per ml with an average of 4.51 µg per ml. In Group II the range was 3.0–16.0 µg per ml and average 10.17 µg per ml. There was no statistically significant difference between the

concentrations of Group I and Group II (median = 12, $x^2 = 1.13$, $P > 0.20$).

Concentration of ethambutol in joint aspirate

The average concentration in tubercular joint aspirate was almost equal to the concentration in the serum (median = 2, $x^2 = 0.05$, $P > 0.30$). Like streptomycin ethambutol also appeared to penetrate freely into the tuberculous joints.

Concentration of ethambutol in cold abscess

The concentration of ethambutol in the cold abscess was almost one third of the concentration in the serum. The difference was statistically significant (median = 8, $x^2 = 57.96$, $P < 0.001$). Spearman's rank correlation between the serum and abscess concentration was statistically significant ($r_s = 0.28$, $P < 0.05$) suggesting that the higher the concentration of ethambutol in serum the higher would be the concentration in the cold abscess.

Reassessment after 3 to 7 months of triple drug therapy

In 4 patients in whom the concentration of drugs was reassessed, no significant change in the pattern of concentration was observed as compared with the pretreatment levels.

DISCUSSION

In the human clinical material there are a large number of variables such as site, duration, extent and pathological state of the lesion, age, nutritional status, metabolic behaviour of the patient, previous treatment, sensitivity and type of infecting organism. Earlier workers (Fellander et al 1952, Katayama et al 1954, Friedman & Kapur 1973) who tried to determine the concentration of streptomycin in tuberculous material in

Table 1 Concentration of streptomycin and ethambutol in serum and tuberculous joint aspirate ($\mu\text{g/ml}$)

Drug	Sample	No of cases	No estimated	Range of concentration	Average concentration	Median concentration
Streptomycin	Serum	14	13	3.5-64.0	23.34	16.0
	Joint aspirate	14	14	3.5-64.0	19.21	8.0
Ethambutol	Serum	14	11	1.9-12.5	4.51	2.0
	Joint aspirate	14	12	1.5-14.2	3.41	2.0

Table 2 Concentration of streptomycin and ethambutol in serum and cold abscess ($\mu\text{g/ml}$)

Drug	Sample	No of cases	No estimated	Range of concentration	Average concentration	Median concentration
Streptomycin	Serum	65	52	1.0-64.0	13.47	8.0
	Cold abscess	66	55	0.5-32.0	6.03	4.0
Ethambutol	Serum	65	53	3.0-16.0	10.17	12.0
	Cold abscess	66	50	1.3-10.5	3.21	2.5

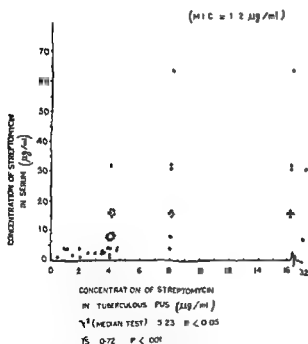


Figure 3 Correlation between the concentration of streptomycin in serum and in tuberculous cold abscess (Group II)

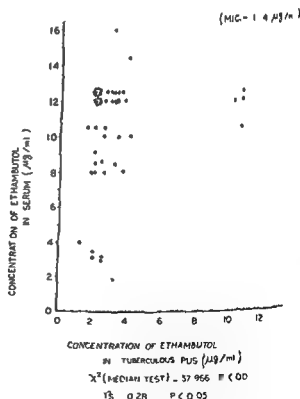


Figure 4 Correlation between the concentration of ethambutol in serum and in tuberculous cold abscess (Group II)

Figures 1 and 2 The corresponding observations in Group II (66 samples from 65 patients) are shown in Table 2, and Figures 3 and 4

Concentration of streptomycin in serum

In Group I and Group II the range of concentration was 3.5-61.0 μg per ml. Statistically the range in both groups was almost equal, the average concentration however, was 23.34 μg per ml in Group I and 13.47 μg per ml in Group II. This difference between the two groups, though statistically insignificant (median = 8, $\chi^2 = 2.41$, $P > 0.10$) may be explained on the basis of the relatively better general condition of the patients in Group I.

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The concentration in the joint aspirate was observed to be almost equal to that of the serum (median = 16, $\chi^2 = 0.1$, $P > 0.50$) meaning that streptomycin flows freely from the serum into the joint without any functioning barrier.

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The range of concentration in 66 samples was 0.5-32.0 μg per ml, with an average of 6.03 μg per ml and median concentration of 4.0 μg per ml. It was observed that there was a significant difference between the serum and pus concentrations (median = 8, $\chi^2 = 5.23$, $P < 0.05$). Spearman's rank correlation coefficient ($r_s = 0.72$, $P < 0.001$) suggested a strong correlation i.e., with higher serum concentration there was a corresponding rise in the concentration in the abscess. In general the concentration in the cold abscess was one third of that in the serum.

Concentration of ethambutol in serum

The concentration in Group I ranged between 1.9-12.5 μg per ml with an average of 4.51 μg per ml. In Group II the range was 3.0-16.0 μg per ml and average 10.17 μg per ml. There was no statistically significant difference between the

concentrations of Group I and Group II (median = 12, $\chi^2 = 1.13$, $P > 0.20$).

Concentration of ethambutol in joint aspirate

The average concentration in tubercular joint aspirate was almost equal to the concentration in the serum (median = 2, $\chi^2 = 0.05$, $P > 0.30$). Like streptomycin ethambutol also appeared to penetrate freely into the tuberculous joints.

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The concentration of ethambutol in the cold abscess was almost one third of the concentration in the serum. The difference was statistically significant (median = 8, $\chi^2 = 57.96$, $P < 0.001$). Spearman's rank correlation between the serum and abscess concentration was statistically significant ($r_s = 0.28$, $P < 0.05$) suggesting that the higher the concentration of ethambutol in serum the higher would be the concentration in the cold abscess.

Reassessment after 3 to 5 months of triple drug therapy

In 4 patients in whom the concentration of drugs was reassessed, no significant change in the pattern of concentration was observed as compared with the pretreatment levels.

DISCUSSION

In the human clinical material there are a large number of variables such as site, duration, extent and pathological state of the lesion, age, nutritional status, metabolic behaviour of the patient, previous treatment, sensitivity and type of infecting organism. Earlier workers (Fellander et al 1952, Katayama et al 1954, Friedman & Kapur 1973) who tried to determine the concentration of streptomycin in tuberculous material in

human skeletal tuberculous lesions observed a wide variation in their results from patient to patient. Similar variations were observed in our study and that is why the data have been statistically analysed for clinical application and the range of concentrations has been mentioned.

Streptomycin concentration in the serum

Streptomycin does not penetrate the erythrocytes, therefore its concentration is approximately twice that in whole blood. The average serum concentration reported by various workers (Katayama et al 1954, Barry 1964, Friedman & Kapur 1973) 3 hours after intramuscular injection of 1 g of streptomycin is estimated to range between 20 and 30 μg per ml approximately. The average serum concentration in our study was 23.34 and 13.47 μg per ml, in Group I and II, respectively. Overall comparison with other reports reveals similar concentrations in different races.

Streptomycin concentration in tuberculous material

Barry (1964) measured that almost 50 to 80 per cent of any drug would reach a tuberculous joint from the blood. Observations in the present report confirm this belief that streptomycin penetrates freely into the intra-articular compartments. The difference between the serum and joint concentrations in our study was statistically insignificant (median = 16, $\chi^2 = 0.1$, $P > 0.50$).

In the cold abscess, Katayama et al (1954) measured 2.7 μg per ml of streptomycin 1½ hours after the administration of ½ g of streptomycin. Fellander et al (1952) and Hever & Risko (1960) observed 2.4 μg of streptomycin 3 hours after the administration of 1 g of streptomycin. In the present series, although there was a wide variation in range (0.5–32.0 μg per ml), in the majority of

the patients the concentration achieved in the abscess was much higher than the minimum inhibitory concentration (MIC) required for most types of human mycobacteria (MIC for most of *Mycobacteria hominis* = 1 μg per ml).

Ethambutol concentration in serum

After oral administration, this drug is readily absorbed and most of the drug circulates accumulated on the surface of the erythrocytes. It is rapidly excreted through the kidneys. Accumulation on the erythrocytes means that the concentration in the serum is almost half that of the whole blood. Most workers (Bobrowitz 1966, Donomae & Yamamoto 1966, Gomez-Pimenta et al 1966, Pyle et al 1966) have reported the ethambutol concentration in the serum to range between 3 and 6 μg per ml under almost similar conditions. The concentration in the serum in the two groups in our series ranged from 1.2 to 16.0 μg per ml.

Ethambutol concentration in tuberculous material

Like streptomycin the average concentration of ethambutol in the joint was similar (Group I, 3.41 μg per ml) as the same as that of the serum (median = 2, $\chi^2 = 0.05$, $P > 0.30$) thus suggesting free flow of the drug into the tuberculous joints.

In Group II, on the other hand, the concentration in the cold abscess (3.21 μg per ml) was about one third of the concentration in the serum (10.17 μg per ml). We could not obtain observations of other workers. The minimum inhibitory concentration of ethambutol for all varieties of mycobacteria is reported to be 1.4 μg per ml of the fluid, though most of the mycobacteria from human clinical tuberculous material are susceptible to 1 μg per ml of ethambutol (Lucchesi et al 1966). Thus, even in Group II, the concentration of ethambutol in the

tuberculous pus was much higher than the required minimum inhibitory concentration of ethambutol for the infecting organisms. The majority of the skeletal tuberculous lesions are caused by the human type of mycobacteria which are expected to respond to concentrations of 1 µg of ethambutol per ml.

Reports of other workers

It has been shown by various workers that radioactive dihydrostreptomycin (Andre 1956, Hanngren & Andre 1964, Lindberg 1967) and radioactive para-aminosalicylic acid (Hanngren 1959) reach skeletal tubercular foci. Radioactive isoniazid (Barclay et al 1953, Canetti 1955) has been reported to diffuse freely into all tissues including bone as well as into abscess cavities and even dried caseous material, in sufficient concentrations to destroy the bacteria. Tuli et al (1974) reported that the concentration of streptomycin in experimental osseous tuberculous lesions after a single intramuscular injection (equivalent to a therapeutic dose) was much higher than that considered inhibitory to the human type of mycobacterium tuberculosis.

Therapy in clinical cases

In clinical practice as a rule more than one drug is administered over a period of time. Isoniazid, the most commonly used drug, has the property of causing vasodilation in the diseased area. Thus it may rationally be expected that the titre of concentration of the individual drugs would be much higher and the cumulative bacteriostatic/bacteriocidal effect would be much greater than that observed after limited doses of the drugs. It is clear that irrespective of the precise pharmacodynamics in clinical practice the concentrations achieved in skeletal tubercular lesions are in excess of the usually accepted inhibitory levels of

the drugs to the mycobacterial organisms. It can be stated with certainty that if the organism is sensitive to the antitubercular drug and the drug is administered for a sufficient period of time the infection may well be controlled and most of the lesions will heal. If a lesion does not come under control the cause is not failure of the drugs to reach the lesion in sufficient concentrations. The cause lies in other factors such as the nature of the mycobacterium (atypical, being generally resistant to first line drugs), the resistance of the infecting organism to the drugs being administered and the mechanical nature of the pathology of the skeletal lesion, e.g. the presence of a large sequestra and areas of extensive destruction.

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REFERENCES

- Allen B. & Baker F. J. (1968) Mycobacteria: isolation, identification and sensitivity testing. F. J. Baker Laboratory aids series.
- Andre T. (1956) Studies on the distribution of tritium labeled dihydrostreptomycin and tetracycline in the body. *Acta radiol (Stockh.)* Suppl. 142.
- Barclay W. R., Fbert H. H., LeRoy G. V., Man thes H. W. & Roth L. J. (1953) Distribution and excretion of radioactive isoniazid in tuberculous patients. *J. Amer. med. Ass.* 151: 1384-1389.
- Barry A. C. (1964) *Chemotherapy of tuberculosis*. Butterworths, London.
- Bobrowitz I. D. (1966) Ethambutol in the treatment of pulmonary tuberculosis. *Ann. N.Y. Acad. Sci.* 135: 921-939.
- Canetti C. (1955) *The tubercle bacillus in the pulmonary lesion of man*. Springer, New York.
- Donomae I. & Yamamoto K. (1966) Clinical evaluation of ethambutol in pulmonary tuberculosis. *Ann. N.Y. Acad. Sci.* 135: 849-881.

- 30 S. M. TULI ET AL.
- Felländer, M, Hierton T & Wallmark, G (1952) Studies on the concentration of streptomycin in the treatment of bone and joint tuberculosis *Acta tuberc scand* 27, 176-189
- Friedman, H & Kapur, V N (1973) Newer knowledge of chemotherapy in the treatment of tuberculosis of bones and joints *Clin Orthop* 97, 5-15
- Gomez-Pimental, J I, Hernandez, H S, Fernandez, I F P, Herrera, R P & Orandas, O G (1966) Retreatment of pulmonary tuberculosis with ethambutol *Ann NY Acad sci* 135 882-889
- Hanngren, A (1959) Studies on the distribution and fate of C 14 and T labeled paminosalicylic acid (PAS) in the body *Acta radiol (Stockh)*, Suppl 175
- Hanngren A & Andre, T (1964) Distribution of 3 H dihydrostreptomycin in tuberculous guinea pigs *Acta tuberc scand* 45 14-20
- Hever, E & Risko, T (1960) Studies on streptomycin levels of blood and abscess *Acta tuberc scand* 38, 40-50
- Katayama, R, Hami, Y, Oyak, K, Tanaka, J & Maruno, T (1954) The chemotherapy of bone and joint tuberculosis Observations on clinical disease *Ann Tuberc* 3 59-94
- Kolmer, J A, Sparelding L H & Robinson, H W (1969) *Approved laboratory technic* Indian V Edition, p 576 Scientific Book Agency, Calcutta
- Lindberg, L (1967) Experimental skeletal tuberculosis in guinea pig A method for producing local lesions and autoradiographic study of their accessibility to tritium labeled dihydrostreptomycin *Acta orthop scand* Suppl 333
- Lucchesi, M, Zubiani M, Termine A & Ros P (1966) Concentrazioni sieriche della etambutole in pazienti trattati con diverse modalità dosaggio *Ann Ist Forlanini* 26 61-69
- Medical Research Council (1973) A controlled trial of ambulant out patient treatment in patient rest in bed in the management of tuberculosis of the spine in young Korean patients on standard chemotherapy *J Bone Jt Surg* 55 B, 678-697
- Pyle, M M, Pfuetz, R H, Pearman M B de Huerga J & Hubble, R H (1966) A four year clinical investigation of ethambutol in initial and retreatment cases of tuberculosis efficacy, toxicity and bacterial resistance *Amer Rev resp Dis* 93 428-441
- Tuli, S M, Brighton, C T, Morton H F, Clark, L W (1974) Experimental induction of localized skeletal tuberculosis lesions and accessibility of such lesions to streptomycin *J Bone Jt Surg* 56 B, 551-559
- Tuli, S M (1975) *Tuberculosis of the spine* Amerind Publishing Co New Delhi

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ISOLATED DISLOCATION OF THE CARPAL SCAPHOID

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A case of isolated dislocation of the carpal scaphoid is presented and the literature on the subject reviewed. An analysis has been made of the cases reported and attention is drawn to certain features which are common to most of the cases.

Key words: scaphoid, carpal dislocation, isolated.

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With the exception of the lunate bone an isolated dislocation i.e. a dislocation unassociated with displacement or fracture of other carpal bones is extremely rare and that of the scaphoid is no exception. It receives but scant attention in many standard textbooks and none at all in others. Nigsi & Buck Gramcko (1975) in their classification of the types of subluxations and luxations of the carpal scaphoid draw attention to its radiological features but a search of the literature reveals that since 1930 only eight cases have been reported: two by Biggs (1930), one each by Bazzy (1931), Kuth (1939), Walker (1943), Russell (1949), Schlossbach (1951), Connell & Dyson (1951). By contrast the other and entirely unrelated type of displacement of the scaphoid (that known as rotational subluxation or dislocation) has been abundantly documented during the same period.

The rarity of isolated dislocation (sometimes referred to as acute dislocation) of the scaphoid merits a report of a further case thus making a total of nine in the last 46 years.

CASE REPORT

A 23 year-old driver of a car was involved in a road accident in February 1976 damaging his right wrist. When seen at the hospital within an hour of the accident his wrist was painful, movements were restricted and there was an abnormally tender bony prominence distal to the radial styloid process. There was no nerve lesion. There was a slight general swelling.

X rays (Figure 1) showed that the scaphoid was dislocated forward and outward but there was no evidence of displacement or fracture of the other carpal bones. There was a fracture at the base of the styloid process of the ulna. Under general anaesthesia reduction was easily achieved by traction on the thumb and fingers and digital pressure on the bony prominence—the bone slipping back into position with a soft snap. Subsequent X rays (Figure 2) showed that the bone had been fully reduced.

The wrist was immobilised in slight dorsal flexion in plaster for 6 weeks. He was then encouraged to put the hand to increasing use. He resumed his normal work as a teacher of pottery in 3 weeks. Eight months after the injury he had no complaints except an occasional ache and was doing his normal work without difficulty. There had been no recurrence of the dislocation. The wrist was normal in appearance and in movements. X rays (Figure 3) showed no evidence of ischaemic necrosis nor of any other abnormality.



Figure 1 Initial displacement of the scaphoid



Figure 2 Full reduction

DISCUSSION

A study of the reports of the eight published cases, together with the one reported here, reveals certain features

which are common to the majority who have suffered this injury

The mechanism In all but one case (Schlossbach 1954) the injury resulted from accidents involving road vehicles

Figure 3 Normal appearances
8 months after the injury



Thus five were sustained whilst riding a motor cycle two whilst driving a car and one on cranking an engine. A factor which is common to all these activities is that the wrist is firmly held in a position of dorsiflexion and ulnar deviation. A sudden violent jerk forcing the hand further in these two directions would have a distraction effect on the radial aspect of the wrist joint and eject the scaphoid in a forward and outward direction. This is the position with slight variation which is seen in the X rays of the majority of the cases. This mechanism suggested by Connell & Dixon (1955) is confirmed by a study of these cases. As a point of interest all reported cases have been men.

Diagnosis and treatment. With one exception all the patients were seen early, usually within hours of the accident and the diagnosis presented no difficulty either by clinical examination alone or by X rays and there was no delay in instituting treatment. Closed reduction was easily accomplished by traction on the fingers and digital pressure on the bony prominence followed by immobilisation

for a few weeks with the wrist in slight dorsiflexion.

Open reduction was very rarely called for when the patients were treated promptly but it became necessary in two cases. Thus Higgs (1930) described how open reduction had to be employed in one of his cases first seen 6 weeks after the injury. Walker (1943) in a case presenting 5 days after the injury failed to reduce by manipulation and even at operation the bone could not be restored to its normal position. He removed it, excised some obstructive tissue and was then able to replace it easily and it remained stable.

Ischaemic necrosis. A remarkable feature in view of the gross displacement of the bone is that this complication is not reported as having occurred in any of the patients. Even in the case described by Walker (1943) and referred to above although the X ray appearances 7 weeks after the operation showed changes suggestive of ischaemia of the scaphoid 7 months later the bone was normal.

Results. The results in all nine cases

whether reduced by closed or open methods, were uniformly good although not necessarily perfect. None suffered from subsequent instability. No doubt such good results are to be attributed to their being seen and diagnosed early and easily (in contrast to many cases of rotational subluxation) and the fact that at this early stage closed reduction is readily accomplished.

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REFERENCES

- Buzby H F (1934) Isolated radial dislocation of the carpal scaphoid. *Ann Surg* 100 551-555.
- Connell M C & Dyson R P (1955) Dislocation of the carpal scaphoid. *J Bone Jt Surg* 37 B 252-256.
- Higgs, S I (1930) Two cases of dislocation of the carpal scaphoid. *Proc roy Soc Med* 23 1337-1339.
- Kuth J H (1939) Isolated dislocation of the carpal navicular. A case report. *J Bone Jt Surg* 21 479-483.
- Nigst H von & Buck Gramcko B (1975) Luxationen und Subluxationen des Kahnbeines. *Handchirurgie* 7, 81-90.
- Russell T H (1949) Intercarpal dislocation and fracture dislocation. *J Bone Jt Surg* 31 B 524-531.
- Schlossbach, T (1954) Dislocation of the carpal navicular bone but not associated with fracture. *J med Soc N J* 51 533-534.
- Walker, G B W (1943) Dislocation of the carpal scaphoid reduced by open operation. *Br J Surg* 30 380-381.

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SOME ASPECTS OF BONE GRAFTING FOR NON-UNION OF THE CARPAL NAVICULAR

Analysis of 41 Cases

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Forty one patients with established non union of the carpal navicular are presented. Forty patients were treated by bone grafting using the same operative technique in all of them. All operated fractures healed and were free of pain at the time of union. Vascularization did not seem to interfere with union in the different types of fractures. Radial styloidectomy performed in addition to bone grafting in 26 of the patients who had arthritic changes improved their wrist mobility.

Key words: carpal navicular, bone grafting, non union.

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There are different points of view concerning open reduction and bone grafting (Gasser 1965, Gordon & King 1961, Graner et al 1966, Milford 1963, Torngren & Sadqvist 1974, Waugh & Reveling 1972). Most authors are rather reluctant to use this procedure for long standing non union with arthritic changes in the wrist joint or fractures involving the upper third of the navicular (Boehler et al 1934, Gasser 1965, Kessler et al 1963, Scholder 1933). In view of this we present our experience with 40 cases of established non union of the carpal navicular treated by bone grafting.

MATERIAL AND METHODS

Forty one patients with non union of the carpal navicular were examined. Forty had open reduction and bone grafting performed and were followed until union was confirmed and wrist motion restored. One patient with a 22 year old

ununioned fracture with no pain and no radial abduction was not operated on (see Discussion). The age of the patients varied between 18 and 32 years with an average age of 24. All of them were healthy normal males.

All patients except for one had a history of a minimum of 1 year of painful limitation of wrist motion affecting daily activity following fracture of the navicular bone. Radiologically there was definite evidence of non union of a fractured scaphoid with signs of necrosis of a fragment in 11 of the patients and arthritic changes around the fracture site in 34. Twenty six fractures were horizontal oblique of the mid third of the bone (Russe 1960), six being displaced. Ten were fractures of the proximal third, four of which were displaced fractures of the lower third of the bone.

The operative technique was that of Russe (1960). In some cases an additional radial styloidectomy was performed. After surgery an above-elbow circular cast was applied for 6 weeks.

The postoperative management was the same in all patients. The cast was removed after 6 weeks and X rays were taken prior to the application of below elbow immobilization. The

whether reduced by closed or open methods, were uniformly good although not necessarily perfect. None suffered from subsequent instability. No doubt such good results are to be attributed to their being seen and diagnosed early and easily (in contrast to many cases of rotational subluxation) and the fact that at this early stage closed reduction is readily accomplished.

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REFERENCES

- Buzby, B I (1934) Isolated radial dislocation of the carpal scaphoid. *Ann Surg* 100 553-555.
- Connell, M C & Dyson, R P (1955) Dislocation of the carpal scaphoid. *J Bone Jt Surg* 37 B 252-256.
- Higgs, S I (1930) Two cases of dislocation of the carpal scaphoid. *Proc roy Soc Med* 23 1337-1339.
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- Nigst, H von & Buck, Gramcko, D (1975) Luxationen und Subluxationen des Kahnbeines. *Handchirurgie* 7 81-90.
- Russell, T B (1949) Intercarpal dislocation and fracture dislocation. *J Bone Jt Surg* 31 B 524-531.
- Schlossbach, T (1954) Dislocation of the carpal navicular bone but not associated with fracture. *J med Soc N J* 51 533-534.
- Walker, G B W (1943) Dislocation of the carpal scaphoid reduced by open operation. *Brit J Surg* 30 380-381.

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REFERENCES

- Buzby H F (1934) Isolated radial dislocation of the carpal scaphoid. *Ann Surg* 100 552-555.
- Connell M C & Dyson R P (1955) Dislocation of the carpal scaphoid. *J Bone Jt Surg* 37 B 252-256.
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- Kuth J R (1939) Isolated dislocation of the carpal navicular. A case report. *J Bone Jt Surg* 21 479-483.
- Nigst H von & Buel Gramcko H (1975) Luxationen und Subluxationen des Kahnbeines. *Handchirurgie* 7 81-90.
- Russell T H (1949) Intercarpal dislocation and fracture dislocation. *J Bone Jt Surg* 31 B 524-531.
- Schlossbach T (1954) Dislocation of the carpal navicular bone but not associated with fracture. *J med Soc N J* 51 533-534.
- Walker, G B W (1943) Dislocation of the carpal scaphoid reduced by open operation. *Br J Surg* 30 380-381.

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casts were changed and X-rays taken every 6 weeks until union was confirmed. When X-ray results were doubtful tomography was performed.

RESULTS

The shortest period of immobilization was 6 weeks, the longest 10 months with an average of four and a half months. All fractures healed with bone grafting and all patients were free of pain at the time of union regardless of the duration of non-union or the type of fracture. The postoperative mobility was improved in more than half of the cases (21) compared to the preoperative range of motion, and most of the patients returned to their original occupation.

In 26 patients, radial styloidectomy was performed at the time of bone grafting. Indications for this additional procedure were: Painful limitation of radial abduction, radiological evidence of narrowing of the radio-navicular space, and local arthritic changes around the radial styloid. Increased mobility, after this treatment, was observed in 13 of the 26 patients, mobility remained unchanged in four and was reduced in nine. All 23 cases with 18 months or less of non-union increased their wrist mobility after surgery, while only four of the 17 patients with more than 18 months of non-union showed improved mobility.

DISCUSSION

Duration of non-union

The term 'non union' of a fracture is time related. Experience shows that prolonged immobilization decreases the incidence of non-union. Certain authors (Boyes 1964) require a minimal period of 3 months, others (McKim 1944), more than 9 months. However prolonged immobilization may be damaging to joint mobility and to muscle power.

In our study of non-union, the period



Figure 1 Thirteen year old non union following failed bone grafting procedure with radio-ulnar styloidectomies



Figure 2 Same case as Figure 1 after second bone grafting procedure. Healing occurred after 7 months of immobilization

prior to surgery varied from 1 to 13 years. The duration of the non union did not affect the final results as far as pain and subsequent union were concerned. In long standing cases (Figures 1, 2) the ultimate result was not influenced by the arthritis which had developed around the radio-navicular joint during this long period. However our study demonstrates that unlike pain or successful union, the improvement of mobility following surgery was related to the preoperative duration of non union. Hence, the post operative mobility of the wrist increased in all 23 cases with 18 months or less of non union while only four of the 17 patients with more than 18 months of non union showed improved mobility.

Vascularization and consolidation

According to Bunnell (1964) the most important reasons for non union of a fracture are excessive mobility at the fracture site and deficiency of the blood supply. According to Boehler (1954), non union will occur in about 10 per cent of all fresh cases even with adequate plaster of paris immobilization and satisfactory blood supply to the



Figure 1 Five year old ununited and untreated fracture of the mid third of the navicular before surgery

fractured fragments. Kessler (1963) maintains that marked displacement of fragments, interposition of soft tissues and incorrect treatment, are the factors responsible for non union and not the vascular insufficiency. In 100 cases of bone grafted scaphoides, Murray (1946) reported a 40 per cent incidence of preoperative aseptic necrosis and yet, all healed following surgery. Trueta (1968) reviewing injected carpal naviculars found the proximal half of the bone to be supplied by some little arterioles scattered about. It was evident to him that slowness of union of a fracture across the neck of the navicular is due to the poor blood supply to the proximal fragment. Talesnik et al (1966) demonstrate in their anatomical study of the carpal navicular vascular anatomy that three branches of the radial artery penetrate the bone from three different



Figure 3 Injected specimen in Spalteholz (volar) aspect radio-carpal joint. Anastomosis between radial and anterior interosseous arteries showing branches to the proximal areas of the navicular and lunate bones (Herness & LeWinn in preparation)

directions; a lateral volar vessel, at the radial articular surface; a dorsal branch, in the area of the insertion of the dorsal radio-carpal ligament, and a more distal branch at the insertion of the lateral radio-carpal ligament. A proximal vessel was also seen in one of the 11 specimens studied.

Our own radio-anatomical studies of injected specimens support the findings of Logrosino & DeMachi (1938), Scholder (1953) and Travagline (1959) of the direct participation of the volar and dorsal interosseous arteries in supplying the proximal areas of the navicular and lunate bones (Herness & Le Winn, in preparation), in addition to the radial artery vascular supply (Figure 3). These various studies show that the proximal, mid, and distal thirds of the bone each has its own source of blood. Hence, vas-



Figure 6 One year old untreated fracture of the proximal third of the navicular



Figure 3 Same case as Figure 4 after bone grafting. Healing occurred after 4 months of immobilization.



Figure 7 Same case as Figure 6 following bone grafting. Union occurred after 4 months of immobilization

cularization of the separated fragments of the fractured bone is only rarely interrupted in most types of fractures. Thus, a year old, untreated and ununited fractures of the mid-third of the bone with a theoretically adequate blood supply

(Russe 1960), necessitated the same immobilization time following surgery as 12 month old fractures of the proximal third with a supposedly poor vascular supply (Figures 4 5 6 7) of the proximal fragment (Russe 1960). This implies that the graft acts as a bridge or a vascular short cut (Boyes 1964) for regenerating bone formation between the separated fragments.

Styloidectomy

Arthritic changes around the radio navicular joint so often seen in radiographies of wrists with ununited fracture of navicular bone are due to changes in the joint stability. This seems to be caused primarily by the displaced and unstable fragments of the fractured navicular bone which cause an abnormal motion at the radio navicular joint (Gray 1959). Limitation of motion at the radio navicular joint especially radial abduction is progressive and causes pain. Hence arthritis with pain and limitation of motion will continue to progress until the fracture is united. Simple styloidectomy will probably not resolve these mutually dependent developments and may even interfere with the natural course of healing. In fact it may further deteriorate wrist mobility. However styloidectomy combined with bone graft



Figure 3 Twenty two year old ununited displaced fracture of the navicular. Marked arthritic changes around the fracture site and the radio navicular joint. Arrow points to calcification along the lateral collateral ligament.

decreased over the years as limitation of radial abduction developed and it had subsided 10 years previously when this motion was entirely abolished.

The second patient (Figure 1) was seen for increasingly severe pain and progressive limitation of motion following an unsuccessful bone grafting of an ununited fracture of the navicular bone with ulnar and radial styloidectomies performed elsewhere. This can be explained by the increased mobility at the fracture site caused by the styloidectomies. Following a second bone graft the fracture united, the pain subsided and the motion improved (Figure 2).

REFERENCES

- Boehler L., Trojan P. & Jahns H. (1954) Behandlungsergebnisse von 734 frischen einfachen Bruehen des Kahnbeinkorpers der Hand. *Wiederherstellungschirurgie* 2: 86-111.

cases. The first one shows the natural course of an untreated fracture. A 22 year old ununited displaced fracture of the upper third of the right navicular was discovered accidentally in a patient seen for other reasons. On examination the patient had no radial abduction of the wrist. X rays of the wrist showed in addition to the fracture marked arthritic changes with narrowing of the radio navicular joint and calcifications along the lateral collateral ligament (Figure 3). The patient reported that pain had

- Boyes, J. H. (1964) *Bunnell's surgery of the hand* 4th ed pp 641-649 J. B. Lippincott Company, Philadelphia
- Gasser, H. (1965) Delayed union and pseudoarthrosis of the carpal navicular Treatment by compression screw osteosynthesis *J Bone Jt Surg* 47 A, 249-266
- Gordon, L. H. & King, D. (1961) Partial wrist arthrodesis *Amer J Surg* 102 460
- Graner, O., Lopes, I. I., Carvalho, H. C. & Atlas, S. (1966) Arthrodesis of the carpal bones in the treatment of Kienbock's disease, painful ununited fracture dislocation of carpal bones *J Bone Jt Surg* 48 A, 767-774
- Gray, H. (1959) *Anatomy of the human body* p 371 Lea and Febiger, Philadelphia
- Kessler, I., Heller, J. & Silberman, Z. (1963) Some aspects in non union of the carpal scaphoide *J Trauma* 3 442-452
- Logroscino, D. & DeMachi, F. (1938) Vascularizzazione e Trofopatie delle ossa del Carpo *Chir Organi Mov* 23 499-524
- Meham, L. H. (1944) Fractures of the carpal scaphoide *Bull Amer Coll Surg* 142 29
- Milford, I. (1963) *Campbell's operative orthopaedics* 4th ed Vol 1, p 683 C. V. Mosby Company, Saint Louis
- Murray, G. (1946) End results of bone grafting for non union of the carpal navicular *J Bone Jt Surg* 28 A, 749
- Russe, O. (1960) Fracture of the carpal navicular, diagnosis non operative treatment and operative treatment *J Bone Jt Surg* 42 A 759-768
- Scholder, P. (1953) Vascularization osseuse et pseudokystes du poignet *Rev Chir orthop* 39 Suppl 1, 1-56
- Taleisnik, J. & Kelly, P. J. (1966) The extraosseous and intraosseous blood supply of the scaphoide bone *J Bone Jt Surg* 48 A 1125-1155
- Torngren, S. & Sadqvist, S. (1974) Pseudoarthrosis in scaphoide bone treated by grafting with autogenous bone peg *Acta orthop scand* 43 82-88
- Travagline, F. (1959) Arterial circulation of the carpal bones *Bull Hosp Jt Dis* 20 24-26
- Trueta, J. (1968) *Studies of the development and decay of the human frame* p 161 Saunders
- Waugh, H. L. & Revling, L. (1945) Ununited fractures of carpal scaphoide, preliminary report on use of vitallium replicas as replacement after excision *Amer J Surg* 67 184

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Madelung's Deformity

A Follow-up Study of 26 Cases and a Review of the Literature

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Madelung's deformity, the history, aetiology, pathogenesis and prognosis, is discussed, on the basis of the literature. The author's material of 26 cases has been followed up. Thirteen of them were treated by resection of the ulna head or shortening of the ulna with or without wedge osteotomy of the radius. The result was an improvement in pain and a cosmetic improvement but mobility was unaltered. Spontaneous improvement in the symptoms is common, so that a waiting policy, and observation of the patient until growth ceases, is recommended.

Key words: deformity of the wrist, dysplasia of bone, dyschondrosteosis, epiphysis growth, Léri-Weill syndrome, Madelung's deformity.

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In 1878, O. Madelung described a severely deformed wrist in a young woman. According to Madelung, this *spontaneous forward subluxation of the hand* (Figure 1) had already been described (Dupuytren 1831, Malgaigne 1855, Weber 1859, Nélaton 1847) and Madelung himself had at that time seen 12 cases. Madelung considered that the deformity was due to a disturbance of the growth of the joint, the result of overloading a joint already predisposed to malformation. The prognosis was good and Madelung advocated the term *manus valga* for the condition. Since then, the topic has fascinated numerous investigators, not least Scandinavians (Poulsen 1904, Natvig 1905, Solberg 1906, Björkroth 1932, Paus 1911, 1951, Bergin 1912, Schulz 1971), and it was Poulsen (1901) who showed that Malgaigne and not Dupuytren should receive the honour of reporting the first



Figure 1 Illustration from Madelung's original study

case of Madelung's deformity (MD). Since then, there has been a growing interest in the disease.

The picture of the disease has been widened and has become increasingly difficult to define, as evidenced by the 33 synonyms which can be encountered in the literature.

In the years 1929 and 1931, Léri & Weill and Léri et al published two cases of genetic dwarfism called dyschondrosteosis, where MD was one of the charac-

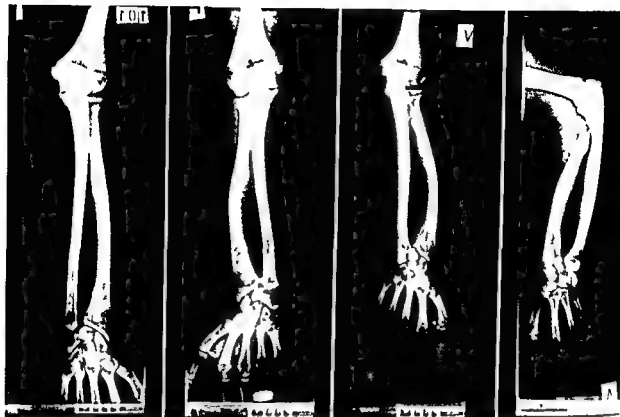


Figure 2 X rays of the forearm in four different patients with Madelung's deformity showing an increasing degree of severity from left to right. The patient on the right shows a malformation of the head of the radius which is never observed in patients with genuine Madelung's deformity.

teristic features. As a consequence of this, several authors have regarded these two diseases as being identical (Herdman et al 1966), whereas others have clearly distinguished between them (Fellmann & Kirkpatrick 1969). Symptomatic cases have also been described simulating Madelung's spontaneous subluxation: traumatic, neoplastic or infectious (Stetten 1909, Björkroth 1932, Anton et al 1938, Stypa 1973), hormonal, biochemical or genetic disturbances (Thompson & Kalayjian 1939, Henry & Thorburn 1967) or in generalized dysplasia of bone (Table 1) (Nassif & Harboyan 1970, Nielsen & Galatius-Jensen 1971). According to Kelikian (1974) seven cases of reversed MD have been described.

It is maintained nowadays that MD is a genetic disorder found more frequently in women than in men, twice as frequently bilaterally and then often with the same degree of severity on both

sides. The condition is localized to the distal epiphysis of the radius, which shows failure of growth, most often in the ulnar/volar portion. Clinically, it appears during the growth period with functional pain and troublesome prominence of the ulnar head, apparent subluxation of the wrist, and curvation and possible shortening of the forearm. The deformity varies from quite mild, symptomless forms to crises of more severe invalidism (Figure 2).

Table 1 Types of bone dysplasia associated with Madelung's deformity

Dyschondrosteosis
Achondroplasia
Multiple exostoses
Multiple epiphyseal dysplasia
Dyschondroplasia (Ollier)

Madelung advised conservative treatment, and Poulsen (1904) reports that

Table 2 Sex distribution and age of onset of the 26 patients with Madelung's deformity (MD) grouped according to the classification of Table 1. The table shows the number of patients operated on the cases with familial disposition and the stature at follow-up examination

Classification	No of ops	♂	♀	Age of onset	No of ops	Familial disp	Stature at follow up examination
Idiopathic MD							
Genuine	13	13	0	6-15 (10½)	7**	2	157-172 cm (160 cm)
Dysplasia*	16	9	1	11-16 (13)	5**	6	137-156 cm (150 cm)
Symptomatic MD	3	0	3	—	1	—	170-188 cm (180 cm)
Total	21	22	4	—	13	8	—

* 9 cases of dyschondrosteosis + 1 case of multiple exostoses

** 1 patient in each group underwent operation on both sides (a total of 15 operations)

surgical intervention with tenotomy of the "contracted" flexors by the method of Busch (1864) was soon abandoned. The first osteotomy of the curved radius for MD was performed by Duplay (1885). Numerous surgical procedures have been recommended in which either the deformity of the radius was attacked or that of the relatively elongated ulna. In some cases both were treated (Poulsen 1904, Stetten 1909, Harrach 1913, Burrows 1937, Helikian 1974).

PATIENTS AND METHODS

A total of 26 patients (22 women and 4 men) with MD attended the Department of Surgery of the Land Orthopaedic Hospital, Copenhagen during the years 1954 to 1974. The symptoms were pain and restricted movement of the wrist which had their onset in the age group 6 to 16 years (familial disposition was frequently ascertained). Patients with bone dysplasia were short in stature. Table 2. MD coincided with other deformities: various small bone cysts, brachial metacarpal sacralisation and double iliac in six out of the nine patients with dyschondrosteosis. This has also been found by other authors (Harris & Thorburn 1967, Savits & Harboyan 1970, Solberg 1966, Stetten 1909, Helikian 1974, Nagura 1971).

In half of the patients the symptoms were pronounced that operation was indicated. The operated patients were between 14 and 37 years

of age (average 22 years). Table 3 shows the operations employed.

Table 3 Fifteen operations for Madelung's deformity in 13 patients

	No of wrists
Excision of the head of the ulna	1
Excision of the head of the ulna + wedge osteotomy of the radius	4
Shortening of the ulna	2
Shortening of the ulna + wedge osteotomy of the radius	1
Resection in the distal ulna	1
Resection in the distal ulna + radio-ulnar arthrodesis distally	3
Total	15

In the case of excision of the head of the ulna a simple resection of the distal head was performed except for the styloid process whose connection with the radius via the articular disc and via the collateral ligament to the carpal bones ensures stability of the wrist. Shortening of the ulna was performed as a Z shaped shortening osteotomy of the distal ulna which was immobilized by means of a plate and screws. Resection of part of the distal ulna (removal of a segment of the shaft of the ulna one cm long about one cm above the radio-ulnar joint distally) was performed to create a pseudarthrosis in order to permit free rotation in the forearm especially in three severe cases.

Table 4 Follow up examination of 26 patients with Madelung's deformity (13 treated operatively)

		Results of follow up examination		
		Improved	Unchanged	Worse
A				
13 patients operated on	Subjective	9	4	0
(7 MD, 5 D, 1 SMD) **	Rotation	1*	10	2
B				
13 patients not operated	Subjective	7	4	2
(6 MD, 5 D, 2 SMD)				

* > 29° increased rotation in the forearm

** MD = Genuine Madelung's deformity, D = dysplasia, SMD = symptomatic Madelung's deformity

In Group A, 8 were working, 4 were at home/school, 1 had a disablement pension

In Group B, 8 were working, 5 were at home/school, 2 had a disablement pension

where the radius had a very steep joint surface (Figure 2, last film). Here, radio ulnar arthrodesis was performed using a screw distally, to avoid ulnar dislocation of the carpus. Of the other 12 wrists, the radius deformity was found to be so pronounced in six cases that in addition to one of the three surgical interventions on the ulna described above, a wedge osteotomy of the radius was performed, a radial skin incision being made and a subperiosteal wedge removed from the distal radius about two cm above the radio ulnar joint. The base of the wedge was positioned more or less dorso radially depending on the steepness of the joint surface and the curvature of the radius. The osteotomy was immobilized with clamps, or bone or periosteal sutures. Reoperation was necessary in three cases: in two of them the ulna was shortened, and in the third a radio ulnar re arthrodesis was performed.

All patients in the group were followed up. The operated patients were seen on an average 8 years and 8 months after the surgical intervention (from 6 months to 20 years).

RESULTS

The results are shown in Table 4. Nine out of thirteen operated patients reported a subjective improvement of their condition in the form of reduced pains. Four patients found their condition unchanged. Physical examination showed that the mobility, especially rotation of the forearm, had been significantly im-

proved (i.e. more than 29°) in only one patient, in ten patients the mobility was generally unchanged and in two patients the range of movement had deteriorated.

Table 5 Classification of Madelung's deformity

- I) Idiopathic Madelung's deformity
 - a) Classic genuine Madelung's deformity
 - b) Dysplasia of bone + Madelung's deformity
- II) Symptomatic Madelung's deformity (Pseudo Madelung's deformity)

DISCUSSION

The literature shows that numerous classifications of a more or less complicated nature have been attempted, based either on morphology or on "aetiology" (Anton et al 1938, Henry & Thorburn 1967, Jaikaran 1969, Kelikian 1974, Malev & Karaganchewa 1975). A new classification which fits in with the material presented here is shown in Table 5.

All idiopathic deformities were found to be bilateral, often unequal, with a considerable preponderance of symptoms on one side. This applied both to patients with genuine classic MD and to patients with dyschondrosteosis or some

other form of bone dysplasia, contrary to the findings of Matev & Karagancheva (1975) and other authors. In both groups there was a familial occurrence of the disease (Table 2), but this was more common in the latter group. More remarkable, however, is the fact that almost all patients in the group with idiopathic MD were women.

Already in his studies Madelung was aware that most often the trouble appeared between the ages of 8 and 14 years, often progressing from initially mild functional pain to fatigue and loss of strength, and finally reduced mobility. After some years the trouble often became stationary, and the pain decreased. Due to this fact a certain period of observation was required in order to be able to reach a decision as to whether or not operation should be performed.

The results show that on an average our patients were operated almost 10 years after onset of symptoms. The reason was our decision to delay operation until termination of growth and closing of the epiphysis of the radius had occurred at the age of 18 to 20 years.

Of the thirteen operated patients, nine felt that the operation had helped, they had less pain, better subjective function and a cosmetically more attractive wrist (Table 4). However, in only one patient was the mobility, especially rotation of the forearm, significantly improved. It had remained more or less unchanged in ten patients, and had deteriorated in two patients. The patient with improved rotation, however, did not experience any beneficial effect from the operation, while the two patients with more limited rotation postoperatively considered that the operation had been helpful. This agrees with the observation that limitation of movement is not a serious complaint. What the patients attach importance to and what leads them to seek medical help is the pain. This was the case in 23 out of the 26 patients in ques-

tion. The last three patients sought treatment for cosmetic reasons due to the prominent head of the ulna.

Based on this investigation, operation cannot be considered of any significant value as regards mobility, but the functional pain decreases and the strength is evaluated subjectively as having increased. Ranawat et al (1957) found similar results. Only a minority of patients require operation.

We have adopted an attitude of reserve, and a longer period of observation is required, at least during the period of growth, before surgical intervention is decided upon and choice is made as to the method preferred.

This material still provides no real aetiological explanation for MD, but some sort of "aetiological" classification as shown in Table 5 would seem rational and easy to grasp.

Conclusion

On the basis of the literature and this material, a new classification of MD is recommended.

Almost all patients included in the investigation with non-traumatic MD are women, and a familial incidence is common.

Because of a difference in the degree of severity, the complaint is often only one-sided. Unilateral deformity was found only in patients with so-called traumatic MD. The most severe cases are found in patients with other forms of bone dysplasia, especially dyschondrosteosis. It is common to find spontaneous improvement in pain and in impaired strength at the end of the growth period. Therefore a period of observation is recommended after closure of the epiphyseal line, before any decision is made to operate.

No specific surgical method can be recommended. The type of intervention must depend on the degree of severity of the deformity. Only a minority of pa-

Table 4 Follow up examination of 26 patients with Madelung's deformity (13 treated operatively)

		Results of follow up examination		
		Improved	Unchanged	Worse
A				
13 patients operated on	Subjective	9	4	0
(7 MD, 5 D, 1 SMD) **	Rotation	1 *	10	2
B				
13 patients not operated	Subjective	7	4	2
(6 MD, 5 D, 2 SMD)				

* > 29° increased rotation in the forearm

** MD = Genuine Madelung's deformity, D = dysplasia, SMD = symptomatic Madelung's deformity

In Group A, 8 were working 4 were at home/school, 1 had a disablement pension

In Group B, 6 were working, 5 were at home/school 2 had a disablement pension

where the radius had a very steep joint surface (Figure 2, last film) Here, radio-ulnar arthrodesis was performed using a screw distally, to avoid ulnar dislocation of the carpus. Of the other 12 wrists, the radius deformity was found to be so pronounced in six cases that in addition to one of the three surgical interventions on the ulna described above, a wedge osteotomy of the radius was performed, a radial skin incision being made and a subperiosteal wedge removed from the distal radius about two cm above the radio-ulnar joint. The base of the wedge was positioned more or less dorso-radially, depending on the steepness of the joint surface and the curvature of the radius. The osteotomy was immobilized with clamps, or bone or periosteal sutures. Reoperation was necessary in three cases, in two of them the ulna was shortened, and in the third a radio ulnar re-arthrodesis was performed.

All patients in the group were followed up. The operated patients were seen on an average 8 years and 6 months after the surgical intervention (from 3 months to 20 years).

RESULTS

The results are shown in Table 4. Nine out of thirteen operated patients reported a subjective improvement of their condition in the form of reduced pains. Four patients found their condition unchanged. Physical examination showed that the mobility, especially rotation of the forearm, had been significantly im-

proved (i.e. more than 20°) in only one patient, in ten patients the mobility was generally unchanged and in two patients, the range of movement had deteriorated.

Table 5 Classification of Madelung's deformity

- | |
|--|
| I) Idiopathic Madelung's deformity |
| a) Classic genuine Madelung's deformity |
| b) Dysplasia of bone + Madelung's deformity |
| II) Symptomatic Madelung's deformity (Pseudo-Madelung's deformity) |

DISCUSSION

The literature shows that numerous classifications of a more or less complicated nature have been attempted, based either on morphology or on "aetiology" (Anton et al 1938, Henry & Thorburn 1967, Jaikaran 1969, Kelikian 1974, Malev & Karagancheva 1975). A new classification which fits in with the material presented here is shown in Table 5.

All idiopathic deformities were found to be bilateral, often unequal, with a considerable preponderance of symptoms on one side. This applied both to patients with genuine classic MD and to patients with dyschondrosteosis or some

other form of bone dysplasia, contrary to the findings of Matev & Karagancheva (1975) and other authors. In both groups there was a familial occurrence of the disease (Table 2), but this was more common in the latter group. More remarkable, however, is the fact that almost all patients in the group with idiopathic MD were women.

Already in his studies Madelung was aware that most often the trouble appeared between the ages of 8 and 14 years, often progressing from initially mild functional pain to fatigue and loss of strength, and finally reduced mobility. After some years the trouble often became stationary, and the pain decreased. Due to this fact a certain period of observation was required in order to be able to reach a decision as to whether or not operation should be performed.

The results show that on an average our patients were operated almost 10 years after onset of symptoms. The reason was our decision to delay operation until termination of growth and closing of the epiphysis of the radius had occurred at the age of 18 to 20 years.

Of the thirteen operated patients nine felt that the operation had helped; they had less pain, better subjective function and a cosmetically more attractive wrist (Table 4). However in only one patient was the mobility, especially rotation of the forearm, significantly improved. It had remained more or less unchanged in ten patients and had deteriorated in two patients. The patient with improved rotation, however, did not experience any beneficial effect from the operation while the two patients with more limited rotation postoperatively considered that the operation had been helpful. This agrees with the observation that limitation of movement is not a serious complaint. What the patients attach importance to and what leads them to seek medical help is the pain. This was the case in 23 out of the 26 patients in ques-

tion. The last three patients sought treatment for cosmetic reasons due to the prominent head of the ulna.

Based on this investigation, operation cannot be considered of any significant value as regards mobility, but the functional pain decreases and the strength is evaluated subjectively as having increased. Ranawat et al (1957) found similar results. Only a minority of patients require operation.

We have adopted an attitude of reserve, and a longer period of observation is required at least during the period of growth, before surgical intervention is decided upon and choice is made as to the method preferred.

This material still provides no real aetiological explanation for MD, but some sort of 'aetiological' classification as shown in Table 5 would seem rational and easy to grasp.

Conclusion

On the basis of the literature and this material, a new classification of MD is recommended.

Almost all patients included in the investigation with non-traumatic MD are women, and a familial incidence is common.

Because of a difference in the degree of severity, the complaint is often only one-sided. Unilateral deformity was found only in patients with so-called traumatic MD. The most severe cases are found in patients with other forms of bone dysplasia, especially dyschondrosteosis. It is common to find spontaneous improvement in pain and in impaired strength at the end of the growth period. Therefore a period of observation is recommended after closure of the epiphyseal line, before any decision is made to operate.

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PAGET'S SARCOMA OF THE VERTEBRAL COLUMN WITH NEUROLOGICAL COMPLICATIONS

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A patient with Paget's sarcoma of the vertebral column who developed cauda equina compression is reported. This is the first report of this condition in an orthopaedic journal. The literature is reviewed. Palliative treatment is recommended.

Key words: complications, osteitis deformans.

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Spinal cord and cauda equina compression is a recognised complication of Paget's disease of the vertebral column (Hartman & Dohn 1966, Miller 1967, Siegelman et al 1969). One hundred and four such cases have been reported in the English literature. Six of these had histological proof of sarcomatous change. We report details of a further patient with sarcoma in Paget's disease of the vertebral column who developed paraparesis.

CASE REPORT

In November 1973 E.H., a 68-year-old woman, first complained of low back pain radiating to both iliac fossae. In January 1974 she was admitted to the general medical ward because of milting and abdominal pains. These complaints changed within 2 weeks to bilateral buttock pain. At which time it was first noted that she had Paget's disease of her lumbar spine and left hemipelvis. She was started on bed rest at home and a surgical steel support. In February 1974 she complained of pain in her right groin radiating to all dermatomes of the right lower limb, with similar less severe pain in the left.

In March 1974 her pain worsened and she

rapidly developed bladder and bowel paresis leading to her admission to Harlow Wood Orthopaedic Hospital.

On examination there was evidence of an incomplete paraplegia with an approximate sensory level at T₁₂. There were no external features of Paget's disease. X-rays again showed Paget's disease of L₂ and sclerosis of L₁. It now seemed that there was possibly some destruction of the right pedicle of L₁. Chest X-ray was normal. Myelography showed a complete block at L₁ level (Figure 1) with features of an extradural compressive lesion on the right side. CSF protein was 200 mg per cent.

It was thought that the neurological condition might be due to structural narrowing of the spinal canal because of Paget's disease of L₁ and L₂, though tumour was considered.

On the 20th of March 1974 a decompressive laminectomy from T₁₂ to L₂ inclusive was performed. The findings were of softened thickened vertebral arches at L₂ and L₃ levels, narrow root canals at L₁ level, thickened dura in all upper lumbar levels but normal dura at L₁ and L₂ levels. There was extensive haemorrhage from the bone during operation, the blood loss totalling 2100 ml. No certain tumour tissue was seen, but specimens were taken from all levels. Histology confirmed Paget's disease affecting all the arches from T₁₂ to L₂. The specimens from the L₁ nerve root canals (the level of myeloid block) revealed a cellular osteosarcoma on the right side with some infiltration at the edge on the left side (Figure 2).

tients require surgical correction, and this rarely improves mobility to a significant degree, although it reduces pain, improves subjective function and results in a cosmetically more attractive wrist

REFERENCES

- Anton J I Reitz G B & Spiegel M H (1938) Madelung's deformity *Ann Surg* 108 411-439
- Bergan F (1942) Madelung's deformitet *Vord Med* 15 2403-2406
- Bjorkroth T (1932) An extraordinary case of deformity of the wrist *Acta orthop scand* 2 242-252
- Burrows H J (1937) An operation for the correction of Madelung's deformity and similar conditions *Proc roy Soc Med* 30 565-572
- Busch W (1864) *Lehrbuch der Chirurgie* Vol 2 p 111 Berlin (quotation from Madelung)
- Dannenberg M Anton J I & Spiegel M H (1939) Madelung's deformity *Amer J Roent genol* 42 671-676
- Darrach W (1913) Habitual forward dislocation of the head of the ulna *Ann Surg* 57 928-930
- Duplay S (1885) De l'ostéomie linéaire du radius pour remédier au difformités poignet soit sponyaneés soit traumatiques *Arch gen Med* 15 385-395
- Dupuytren G (1834) *Leçon Orale de Clinique Chirurgicale* Faites a l'Hotel Dieu de Paris 4 197 (quotation from Madelung)
- Felmann A H & Kirkpatrick J A (1969) Madelung's deformity Observations in 17 patients *Radiology* 93 1037-1042
- Henry A & Thorburn M J (1967) Madelung's deformity *J Bone Jt Surg* 49 B 66-73
- Herdman R C Langer L O & Good R A (1966) Dyschondrosteosis The most common cause of Madelung's deformity *J Pediatr* 68 432-441
- Jaikaran S (1969) *The growth plate and its disorders* pp 104-109 Iivingstone Ltd Edinburgh and London
- Kelikian H (1974) *Congenital deformities of the hand and forearm* pp 753-779 Saunders Co London
- Jéri A & Weill J (1929) Une affection congenitale et symétrique du développement osseux la dyschondrostéose *Bull Soc Méd Hop Paris* 53 1491-1494
- Léri A Layant F & Weill J (1931) La dyschondrostéose variété nouvelle de nanism *Presse Méd* 39 262-264
- Madelung O W (1878) Die spontane Subluxation der Hand nach vorne *Arch Klin Chr* 23 395 und *Verh dtsch Ges Chr* 7 259-276
- Malgaigne J F (1855) *Traité des Fractures et des Luxations* 2 711-713 Paris (quotation from Madelung)
- Matev I & Karagancheva E (1975) The Madelung deformity *The Hand* 7 152-158
- Nagura S (1971) Über die Madelung'sche Deformität *Z Orthop* 109 813-816
- Nassif R & Harboyan G (1970) Madelung's deformity with conductive hearing loss *Arch Otolaryng* 91 175-178
- Nélaton A (1847) *Luxations du Poignet* Eléments de pathologie chirurgicale 2 405 Paris (quotation from Madelung)
- Natvig R (1905) Madelung's haanddeformitet *T norske Lægeforen* 25 535-535
- Nielsen H & Galatius-Jensen P (1971) Familieundersøgelser over dyschondrosteosens manifestationer *Foredrag ved Nordisk Forening for Medicinsk Radiologi* 31 kongres Island
- Paus H (1941) Madelung's deformity *Viden skabs Akademiets Skr* No 8 Oslo
- Paus B (1951) Madelung's deformity Its etiology and pathogenesis *Acta orthop scand* 20 249-258
- Poulsen K (1904) Om den Madelung'ske deformitet af Haanden *Hospitalstidende* 33 817-838
- Ranawat C S DeFiore J & Straub I R (1975) Madelung's deformity *J Bone Jt Surg* 57 A 772-775
- Schulstad I (1971) Madelung's deformity with extensor tendon rupture *Scand J plast reconstr Surg* 5 153-155
- Solberg M (1906) To tilfælde af Madelung's haanddeformitet *T norske Lægeforen* 26 195-196
- Stetten B W (1909) Idiopathic progressive curvature of the radius or so called Madelung's deformity of the wrist *Surg Gynec Obstet* 8 4-31
- Stýpa Z (1973) Post traumatic Madelung's deformity of the hand *Acta Chr orthop Traum Cech* 40 436-443
- Thompson C F & Kalayjian H (1939) Madelung's deformity and associated deformity at elbow *Surg Gynec Obstet* 69 221-230
- Weber C O (1859) *Chirurgische Erfahrungen und Untersuchungen* p 232 Berlin (quotation from Madelung)

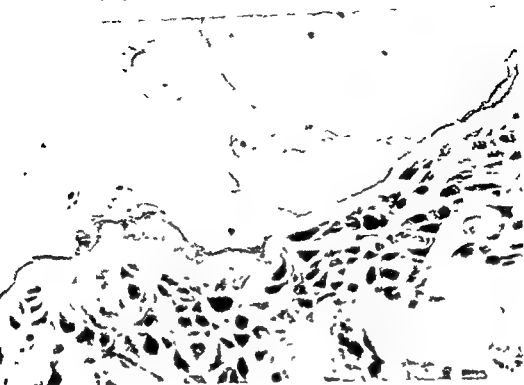


Figure 2 Paget's disease of bone with cement mosaic rimmed by malignant osteoblasts

column. When treated by decompressive laminectomy a gratifying result may be expected (Hartman & Dohn 1966, Klenerman 1966, Miller 1967, Siegelman et al 1968, Direkse & Milnes 1970, Carlidge et al 1972). Of the 104 cases so far reported, 69 had operative decompression and 58 had definite, though variable, relief of pain and neurological signs (Feldman & Seaman 1969, De Rose et al 1971, Carlidge et al 1972, Sadar et al 1972, Melick et al 1978).

The true incidence of sarcomatous change in Paget's disease remains uncertain. When it occurs the sites commonly involved are the femur, pelvis, humerus and skull in that order (Porrett et al 1957, Schajowicz & Skulhiet 1966, Barry 1969).

Vertebral Paget's disease with sarcomatous change is exceedingly rare (Porrett et al 1957, Price & Goldie 1969). Including our patient there are now

seven reported cases of histologically proven Paget's sarcoma of the vertebral column causing neurological complications.

The seven case reports are summarized in Table 1. Symptoms of backache or sciatica had been present for an average of 13 months (range, 2 weeks to 4 years). Neurological signs were present on average two and a half months (range, 1 week to 12 months). At least two patients (nos 5 and 7) showed no external evidence of Paget's disease. Paraparesis of varying degree was present in all patients on admission to hospital. A correct radiological diagnosis was made in the first three cases only. Polyostotic Paget's disease was present as a rule and a block was seen on the myelogram whenever myelography was performed.

Temporary (approximately 1 month) relief of pain and neurological signs was gained by all the five patients who had



Figure 1 Sclerosis of the bodies of L_1 and L_2 with possible destruction of right pedicle at L_1 , a complete block to the flow of myodil at L_1 level

On the day after operation the patient noted relief of pain and some recovery of power in the right leg. By the eleventh postoperative day she had regained bladder and bowel control and began exercising out of bed. One month post-operatively a right pleural effusion was noted. This was aspirated but soon recurred and a week later one and a half litres of haemorrhagic fluid was withdrawn. Subsequently lung metastases were noted in the left mid zone. In spite of teletherapy her condition deteriorated rapidly and she died on the 13th of May 1974. Permission for post mortem examination was denied.

DISCUSSION

It is now 100 years since Sir James Paget of St Bartholomew's Hospital, London, presented his original paper describing the condition he called osteitis deformans (Paget 1877). This disease is said to occur in 3.7 per cent of the population over 40 years of age (Collins 1956). The majority are subclinical cases, the pa-

thology commonly involving the silent areas with lumbo-sacral spinal involvement in 76 per cent of cases (Dickson et al 1945, Collins 1956).

Vertebral Paget's disease causing neurological complications is rare—only 104 cases have been reported. Wylie (1923) was the first to describe this problem. Turner (1940) reviewed 34 cases and suggested the pathogenesis of neurological signs to be due to

- progressive bony expansion causing spinal compression,
- cord ischaemia without spinal obstruction,
- vertebral displacement.

The typical patient is said to be a middle-aged male with a history of 12 months insidious progressive paraparesis. X-ray signs of Paget's disease in the thoracic spine and a block in the myodil



Figure 2. Paget's disease of the vertebrae showing metastatic giant osteoblasts.

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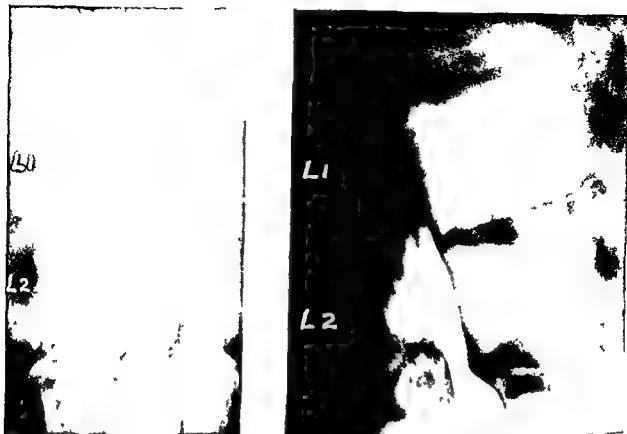


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Table 1. Paget's sarcoma of the vertebral column

Case	Progress	Histopathology
Paget's subhyaline L ₁ and multicentric sarcoma	Death within 3 months No operation	Sarcoma L ₁ L ₂ L ₃
Osteolytic Paget's and filling defects L ₄ L ₅ S ₁ levels	Home 1 month Death 5½ months post op + DXT	Chondrosarcoma
Vertebral Paget's Myeloblast T ₃₋₄	Home 1 month Death 5 months post-op	Osteosarcoma
Myeloblastic Paget's Myeloblast L ₁	Slight improvement Death 8 weeks post op	Osteosarcoma
Osteolytic Paget's Myeloblast	Death shortly No operation	Osteosarcoma
Osteolytic Paget's Myeloblast T ₁ + L ₁	Urine control 3 days Death 5 months post op	Osteosarcoma
Osteolytic Paget's Myeloblast L ₁	Visceral control 10 days Walking 2 weeks Death 7 weeks post-op + DXT	Osteosarcoma L ₁

REFERENCES

- Barry H C. (1969) *Paget's disease of bone* pp 136-193 F and S Livingstone Ltd., Edin-
burgh and London
- Campbell E & Whitfield R D. (1943) Osteo-
genic sarcoma of vertebrae secondary to
Paget's disease *N Y St J Med* 43 931-938
- Cartledge J F, McCollum J P & Ayar
R D A. (1972) Spinal cord compression in
Paget's disease *J Neurol Neurosurg Psychiat*
33 875-879
- Clifton H H. (1936) Paget's disease of bone
Incidence and subclinical forms *Lancet* ii
51-52
- Davie T B & Cooke W F. (1937) Supervention
of osteogenic sarcoma in Paget's disease *Brit
J Surg* 23 299-316
- De Rose J J, Wallach S & Baker R H. (1971)
Long term treatment of Paget's disease in
outpatients with porcine calcitonin (CT)
Ann Med 12 473
- Dickinson D, Campbell J H & Ghormley R H.
1915 Osteitis deformans: Paget's disease of
bone *Radiology* 4 449-450
- Dickinson H & Milnes J V. (1970) Spinal cord
compression in Paget's disease *Brit J Surg*
57 233-240
- Fellman H & Seaman W B. (1977) The neuro-
logical complications of Paget's disease in the
cervical spine *Amer J Roentgenol* 105 375-
382
- Finneson B F, Goluboff B & Shepley H A.
(1958) Sarcomatous degeneration of osteitis
deformans causing compression of the cauda
equina *Neurology (Minneapolis)* 8 82-84
- Hartman J T & Dohn H F. (1966) Paget's
disease of the spine with cord or nerve root
compression *J Bone Jt Surg* 48 A 1079-
1081
- Klennerman L. (1966) Cauda equina and spinal
cord compression in Paget's disease *J Bone
Jt Surg* 48-B 365-370
- Melick R A, Ebeling P & North J J. (1976)
Improvement in paraplegia in vertebral
Paget's disease treated with calcitonin *Brit
med J* i 627-628
- Miller J D. (1967) Spinal compression due to
Paget's disease of bone *Scot med J* 12
441-445
- Paget J. (1847) On a form of chronic inflamma-
tion of bones (osteitis deformans) *Med-chir
Trans* 60 27-62
- Porretta C A, Dahlin D C & Jones J M.
(1937) Sarcoma in Paget's disease of bone
J Bone Jt Surg 39 A 1314-1323
- Price C H G & Goldie W. (1969) Paget's
sarcoma of bone *J Bone Jt Surg* 51 B 205-
206
- Sadler E S, Walton R J & Grossman H H.

Table 1 Summary of the seven case reports

Cases reported	History	Examination
1 42 year-old male (Davie & Cooke 1937)	4 years leg pains 3 months weak left leg	Paraplegia
2 52 year old male (Campbell & Whitfield 1943)	4 months right sciatica 1 month frequent micturition	(Cauda equina signs)
3 53-year-old male (Campbell & Whitfield 1943)	1 month back pain 1 week leg weakness	Spastic paresis Distended bladder
4 64 year old female (Finneson et al 1958)	4 years low back pain 1 month bilateral sciatica + leg weakness	Flaccid paraplegia with incontinence
5 64 year old male (Barry 1969)	12 months difficulty walking	Spastic paraparesis T ₃ level
6 53 year old male (Sadar et al 1972)	2 weeks bladder paresis	Flaccid paraparesis T ₁₁ level + sphincter loss
7 58-year-old female (Shannon & Hopkins 1977)	4 months low back pain 2 weeks paraparesis	Flaccid paraparesis + sphincter loss

operative decompression performed. All patients died within 6 months of admission (average 4.2 months). Widespread metastases were seen in the four patients on whom post-mortem examinations were recorded.

Conclusions

It is important to recognise benign lesions causing spinal cord and root compression. Paget's disease of the vertebral column, often seen in orthopaedic clinics, sometimes causes backache, but seldom causes neurological complications. Cord and root compression in Paget's disease of the spine is rarely due to malignant change. The vast majority of patients with spinal compression who develop slowly progressive paraparesis (12 months) have simple Paget's disease (Turner 1940, Sadar et al 1972). For these patients operative decompression should be advised since this frequently provides prolonged relief (Miller 1967,

Siegelman et al 1968, Direkse & Milnes 1970, Cartledge et al 1972).

A rapidly developing paraparesis (2 to 3 months) in a patient with Paget's disease of the spine suggests sarcomatous change. This possibility should be confirmed histologically.

In view of the inevitably rapid fatal outcome in the patient with sarcoma, the value of an extensive spinal decompression must be questioned. The histological diagnosis may well be established by a simpler procedure such as a needle or limited open biopsy, allowing palliative treatment of a non-surgical nature to be undertaken.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs Brackenbury and Harrison for the photographs.

f Paget's sarcoma of the vertebral column

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Polyostotic Paget's Woodil block T ₁ + I	Urine control 3 days Death 5 months post op	Osteosarcoma
Polyostotic Paget's Woodil block L	Ureteral control 10 days Walking 2 weeks Death 7 weeks post op + DXT	Osteosarcoma L ₁

REFERENCES

- Barry H C. (1969) *Paget's disease of bone* pp 136-193 E and S Livingstone Ltd., Edinburgh and London
- Campbell M & Whitfield R D (1943) Osteogenic sarcoma of vertebrae secondary to Paget's disease *N Y St J Med* 43 931-938
- Cartledge N E F, McCollum J P K & Ayar R M A (1972) Spinal cord compression in Paget's disease *J Neurol Neurosurg Psychiat* 35 820-828
- Collins D H (1936) Paget's disease of bone: Incidence and subclinical forms *Lancet* ii 51-57
- Davis T D & Cooke W E (1937) Supervention of osteogenic sarcoma in Paget's disease *Brit J Surg* 25 299-316
- De Rose J J, Wallach S & Baker H K (1971) Long term treatment of Paget's disease in outpatients, with portable calcitonin (CT) (in Res 111 471)
- Dickson D D, Camp J D & Ghormley R K. " " " " " "
- Dir " " " " " " " " " " " "
- compression in Paget's disease. *Brit J Surg* 57 239-240
- Feldman F & Seaman W B (1969) The neurological complications of Paget's disease in the cervical spine *Amer J Roentgenol* 105 375-381
- Finneson B M, Goluboff H & Shenkin H A (1958) Sarcomatous degeneration of osteitis deformans causing compression of the cauda equina. *Neurology (Minneapolis)* 8 82-83
- Hartman J T & Dohn H F (1966) Paget's disease of the spine with cord or nerve root compression *J Bone Jt Surg* 48-A 1079-1083
- Klenerman L (1966) Cauda equina and spinal cord compression in Paget's disease *J Bone Jt Surg* 48-B 360-370
- Melick R A, Ebeling P & Horth R J (1976) Improvement in paraplegia in vertebral Paget's disease treated with calcitonin *Brit med J* 1 627-628
- Miller J D (1967) Spinal compression due to Paget's disease of bone *Scol med J* 12 441-445
- Paget J (1877) On a form of chronic inflammation of bones (osteitis deformans). *Med-chir Trans* 60 57-63
- Porretta C A, Dahlis D C & Jones J H (1957) Sarcoma in Paget's disease of bone *J Bone Jt Surg* 39 A 1314-1323
- Price C H G & Goldie W (1969) Paget's sarcoma of bone *J Bone Jt Surg* 51 B 200-224
- Sadar E S, Walton R J & Gossman H H

Table 1 Summary of the seven case reports

Cases reported	History	Examination
1 42-year old male (Davie & Cooke 1937)	4 years leg pains 3 months weak left leg	Paraplegia
2 52-year old male (Campbell & Whitfield 1943)	4 months right sciatica 1 month frequent micturition	Cauda equina signs
3 53-year-old male (Campbell & Whitfield 1943)	1 month back pain 1 week leg weakness	Spastic paresis Distended bladder
4 64-year old female (Finneson et al 1958)	4 years low back pain 1 month bilateral sciatica + leg weakness	Flaccid paraplegia with incontinence
5 64-year-old male (Barry 1969)	12 months difficulty walking	Spastic paraparesis T ₁ level
6 53-year old male (Sadar et al 1972)	2 weeks bladder paresis	Flaccid paraparesis T ₁₁ level + sphincter loss
7 58-year-old female (Shannon & Hopkins 1977)	4 months low back pain 2 weeks paraparesis	Flaccid paraparesis + sphincter loss

operative decompression performed. All patients died within 6 months of admission (average 4.2 months). Widespread metastases were seen in the four patients on whom post-mortem examinations were recorded.

Conclusions

It is important to recognise benign lesions causing spinal cord and root compression. Paget's disease of the vertebral column, often seen in orthopaedic clinics, sometimes causes backache, but seldom causes neurological complications. Cord and root compression in Paget's disease of the spine is rarely due to malignant change. The vast majority of patients with spinal compression who develop slowly progressive paraparesis (12 months) have simple Paget's disease (Turner 1940, Sadar et al 1972). For these patients operative decompression should be advised since this frequently provides prolonged relief (Miller 1967,

Siegelman et al 1968, Direkse & Milnes 1970, Carlidge et al 1972).

A rapidly developing paraparesis (2 to 3 months) in a patient with Paget's disease of the spine suggests sarcomatous change. This possibility should be confirmed histologically.

In view of the inevitably rapid fatal outcome in the patient with sarcoma, the value of an extensive spinal decompression must be questioned. The histological diagnosis may well be established by a simpler procedure such as a needle or limited open biopsy, allowing palliative treatment of a non surgical nature to be undertaken.

ACKNOWLEDGEMENTS

The authors wish to thank Messrs Brackenbury and Harrison for the photographs.

of Paget's sarcoma of the vertebral column

Case	Progress	Histopathology
Paget's subluxation L ₁ and mult. centre sarcoma	Death within 3 months No operation	Sarcoma L ₁ L ₂ L ₃
Polystotic Paget's and filling defects L ₄ L ₅ S ₁ levels	Home 1 month Death 5 1/2 months post op + DXT	Chondrosarcoma
Vertebral Paget's Myeloid block T ₂₋₄	Home 1 month Death 5 months post-op	Osteosarcoma
Polystotic Paget's Myeloid block L	Slight improvement Death 6 weeks post op	Osteosarcoma
Polystotic Paget's Not x-rayed	Death shortly No operation	Osteosarcoma
Polystotic Paget's Myeloid block T ₁ + I	Urine control 3 days Death 3 months post op	Osteosarcoma
Polystotic Paget's Myeloid block L	Visceral control 111 days Walking 2 weeks Death 7 weeks post op + DXT	Osteosarcoma I ₁

REFERENCES

- Barry H C (1963) *Paget's disease of bone* pp 136-193 E and S Livingstone Ltd., Edinburgh and London
- Campbell H & Whitfield R D (1943) Osteogenic sarcoma of vertebrae secondary to cervical spine Amer J Roentgenol 105 375-382
- Finneson B F., Goluboff B & Shenkin H A. (1958) Sarcomatous degeneration of osteitis deformans causing compression of the cauda equina Neurology (Minneapolis) 8 82-84
- Hartman J T & Dohn H F (1966) Paget's disease of the spine with cord or nerve root compression J Bone Jt Surg 48 A 1079-1084
- Kleerman L (1966) Cauda equina and spinal cord compression in Paget's disease J Bone Jt Surg 48-B 365-370
- Melick R A., Ebeling W & Hjorth R J (1976) Improvement in paraplegia in vertebral Paget's disease treated with calcitonin Brit med J 1, 627-628
- Miller J D (1967) Spinal compression due to Paget's disease of bone Scot med J 12 411-413
- Paget J (1877) On a form of chronic inflammation of bones (osteitis deformans) Med chir Trans 60 37-63
- Porretta C. A., Dahlin D C. & Jones J W (1957) Sarcoma in Paget's disease of bone J Bone Jt Surg 39 A 1314-1329
- Price C. H. H. & Goldie W (1969) Paget's sarcoma of bone J Bone Jt Surg 51 B 205-224
- Sadar F S., Walton R J & Gossman H H
- So 825-83
- Collins D H (1956) Paget's disease of bone Incidence and subclinical forms Lancet ii 51-57
- Davis T H & Cooke W E. (1937) Supervention of osteogenic sarcoma in Paget's disease Brit J Surg 25 299-316
- De Rose J J Wallach H & Baker R L. (1971) Long term treatment of Paget's disease in outpatients with porcine calcitonin (CT) Clin Res 19 474
- Dickson D D Camp J D & Ghormley R L. (1945) Osteitis deformans Paget's disease of bone Radiology 44 449-470
- Grekse W & Mlues J V. (1970) Spinal cord compression in Paget's disease Brit J Surg 57 239-240
- Feldman F & Seaman W B (1969) The neurological complications of Paget's disease in the

- (1972) Neurological dysfunction in Paget's disease of the vertebral column *J Neurosurg* **37** 661-665
- Schajowicz F & Stultzel I (1966) Giant cell tumour associated with Paget's disease of bone. A case report *J Bone Jt Surg* **48 A** 1340-1349
- Siegelman S S, Levine S A & Walpin I (1968) Paget's disease with spinal cord compression *Clin Radiol* **19** 421-425
- Turner J W A (1940) The spinal complications of Paget's disease (osteitis deformans) *Brain* **63** 321-349
- Wyllie W G (1923) The occurrence in osteitis deformans of lesions of the central nervous system with a report of four cases *Brain* **46** 336-351

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PROCESSUS SUPRACONDYLOIDEA HUMERI WITH CONCOMITANT COMPRESSION OF THE MEDIAN NERVE AND THE ULNAR NERVE

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Compression of the median nerve and the ulnar nerve due to the anatomical anomaly processus supracondyloidea humeri is a rare condition. A case of combined median and ulnar nerve compression is described. Diagnostics and treatment are discussed in the light of the present case history and those described in the literature. The conclusion is that the treatment should be subperiosteal resection of the process together with the origin of the pronator teres muscle.

Key words: supracondylar process, anatomical variation, nerve compression, median nerve, ulnar nerve, operative treatment.

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Processus supracondyloidea humeri (PSH) is a well known congenital and often hereditary anatomical variation which in the European population occurs with a frequency of approximately 1 per cent (Terry 1930).

Due to its anatomical location PSH may in rare cases result in compression of the median nerve, the ulnar nerve and the brachial artery. In the literature, 13 cases have been described of definite symptomatic compression of the median nerve due to PSH (Barnard & McCoy 1946, Gantert & Alzheimer 1956, Goulon et al 1963, Kessel & Rang 1966, Mandruzic et al 1938, Moraes 1950, Mumenthaler 1961, Soleri 1929). There have been four cases of compression of the ulnar nerve (Fragiadakis & Lamb 1970, Goulon et al 1963, Mumenthaler 1961) as well as one case with combined compression of the median and the ulnar nerve (Mumenthaler 1961).

The purpose of this paper is to describe a case of combined compression of the median and the ulnar nerve.

CASE REPORTS

A 20 year old female clerk was referred to the department in October 1974 after 6 months with symptoms of right sided compression of the ulnar nerve and to a lesser extent of the median nerve as well without any history of injury. The symptoms consisted of paraesthesia and dysaesthesia in all five fingers. Furthermore there were symptoms of hypersensitivity to cold, increased sweating, a feeling of rigidity and slightly reduced strength.

The symptoms were aggravated by use of the hand and fingers particularly during pronation of the forearm but they also continued as resting phenomena after working for some length of time. There was also pain along the inside of the upper arm and gradually the symptoms began to interfere with the patient's work.

On examination she had light dysaesthesia of all fingers but no atrophy or paresis of the hand muscles. Five centimeters proximal to the



Figure 1 The supracondylar process the position of the median nerve and the brachial artery and branches (From Kohler & Zimmer 1967)

medial epicondyle a pressure tender bony prominence could be felt and pressure in this area caused paraesthesia in all of the hand. There was normal pulsation. Roentgenograms of the right elbow and upper arm showed a 15 mm long processus supracondyloideus humeri. At operation a distended median nerve and brachial artery were found passing beneath the process from behind and continuing profound to the part of the pronator teres muscle which originated from the process. The ulnar nerve passed behind the brachial artery and behind the process but close to the latter. The nerves were found to be slightly succulent and greyish. The bony process was chiselled subperiosteally and removed along with the connecting part of the pronator teres muscle allowing the artery and nerves to pass without stretching. There were no symptoms at all after 3 weeks but after 2 months the patient complained of recurrence of the symptoms of ulnar nerve compression in the right arm. At objective examination the only symptom appeared to be percussion paraesthesia released from the upper edge of the cubital tunnel. A simple decompression of the ulnar nerve was carried out and the nerve was found

to be without changes. The previous field of operation was explored but osseous recurrence or cicatricial changes as the reason for the ulnar compression were not found.

There was an instant relief after this intervention. However, 6 weeks later gradually increasing ulnar nerve compression symptoms recurred little by little with release of percussion paraesthesia from the area around the previous PSH. Eight months after the second operation an anteponition of the right ulnar nerve was carried out and compressing cicatricial fibrosis was found around the ulnar nerve for a distance of approximately 4 cm just distal to the previous PSH.

After the latter operation the symptoms disappeared gradually, and at a follow up examination 4 months later the patient had been back to full time work for 3 months. From time to time there had been only very brief par-



Figure 2 A ray of the right humerus in our patient showing the supracondylar process

aesthesia like sensations in the fourth finger which had not interfered with her work. Objective examination showed no difference between the two upper extremities and there was no sign of osseous recurrence.

DISCUSSION

Symptomatic nerve compression caused by PSII is, according to the literature, exceedingly rare and consequently it might be overlooked even if the diagnosis is relatively easy.

Compression of the median nerve is much more frequent than compression of the ulnar nerve, most likely because the ulnar nerve, as described by Goulon et al (1963), rarely takes a course which brings it in direct contact with PSII.

The diagnosis is based on non traumatic median or ulnar nerve compression related to a palpable and roentgenologically apparent beak like prominence in an anteromedial position on the distal humerus. It is characteristic that the symptoms are aggravated by lower arm pronation as described by Barnard & McCoy (1946) which was also the case in the patient presented here. Among others Kessel & Rang (1966) have described compression of the brachial artery or, in cases of a high division of this artery, of the ulnar artery, giving ischaemic pain in the forearm and the hand—forearm claudication. In the patient presented here there was peroperative indication of light compression of the brachial artery, but no symptoms of forearm claudication.

According to most authors, the treatment of PSII consists of operation with subperiosteal resection of the process and the part of the pronator teres muscle

which originates from it. Subperiosteal chiselling is necessary in order to avoid recurrence of PSII, as in the case presented by Solieri (1929).

The reason why the present patient had to be operated upon three times was the fact that besides symptomatic PSII she developed both compression of the ulnar nerve in the cubital tunnel and postoperative perineural fibrosis.

REFERENCES

- Barnard L H & McCoy S H (1946) The supracondylar process of the humerus. *J Bone Jt Surg* 28 845-850.
- Fragiadakis H G & Lamb D W (1970) An unusual cause of ulnar nerve compression. *The Hand* 11 14.
- Gantert F & Alzheimer C. (1936) Der Processus Supracondylaricus Humeri als Ursache von Medianusbeschädigungen. *Nervenarzt* 27 319-353.
- Goulon M, Lord G & Bedolsean M (1963) Lésions du médian et du cubital apophysaire sus-épitrochléenne. *Presse med* 71 2355.
- Kessel L & Rang M (1966) Supracondylar spur of the humerus. *J Bone Jt Surg* 48 B 765-769.
- Köhler A & Zimmer E E (1967) Grenzen des Normalen und Anfänge des Pathologischen im Röntgenbild des Skelets. 11. Auflage. Georg Thieme Verlag Stuttgart.
- Mandruzzato F (1938) Patologia e chirurgia del processo sopraepitrocleare dell'omero. *Chir Organi Mov* 24 123-132.
- Moraes F (1950) Sur un cas d'apophyse sus-épitrochléenne avec manifestation clinique. *Rev Orthop* 36 30-34.
- Mumenthaler M (1961) De Ulnarisparese. pp 279-315. Georg Thieme Stuttgart.
- Solieri H (1929) Neuralgia del nervo Mediano de processo sopraepitrochleare. *Chir Organi Mov* 14 171-180.
- Terry R J (1930) On the racial distribution of the supracondylar variation. *Amer J phys Anthropol* 14 459-462.

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THE MONK HIP ARTHROPLASTY

Preliminary Report on the Uncemented Standard Monk Prosthesis

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The Monk hip prosthesis is a one piece block prosthesis consisting of a metal femoral component with the head enclosed in a polyethylene cup. The standard type is fixed without cement. Most of the hip movements take place between the metal and the polyethylene cup. 164 Monk arthroplasties were performed. 95 hips in 88 patients have been available for regular examination and follow-up. The follow up period was from 12 to 30 months, an average of 19 months. Out of the 95 cases, 72 were classified as excellent, 10 as good and 13 as unchanged. The results obtained during the first year were comparable to those obtained with the Ring prosthesis, but during the following 1½ years eight revisions had to be performed. The main reason for the deterioration was loosening of the femoral component, probably because in the standard type it is too short and the neck has too great a varus inclination resulting in a rather strong tilting force. Because no cement has been used the revisions have been quite easy to perform. Another reason for failure has been wear of the polyethylene cup, in one case with a massive foreign body reaction. In spite of a short follow-up period this report illustrates the failures due to the design of the prosthesis, and therefore an improved construction is now in use.

Key words: bipolar system, block prosthesis, Monk arthroplasty, Ring arthroplasty, total hip replacement, uncemented hip prosthesis.
Accepted 2 iii 77

The use of acrylic cement has created many problems and complications. This fact has initiated many attempts to construct an uncemented total hip prosthesis. One of the best known uncemented hip prostheses is the Ring prosthesis, introduced by Ring in 1964 (Ring 1974). We have used it for some years, and an assessment made together with several other Danish orthopaedic departments revealed results similar to those obtained with the various cemented types (Paaby 1974).

In February 1974 we started to use the prosthesis developed by Monk in Liverpool, for several reasons. The Monk prosthesis has a metal-to-polyethylene articulation, it is constructed as a one-piece block prosthesis which is quite easy to handle, and the operative procedure causes less trauma than the Ring operation.

The Monk prosthesis consists of a metal femoral component shaped somewhat like the well-known Moore prosthesis, but with a smaller head. The head

is enclosed in a polyethylene cap. When placed in the acetabulum most of the movement takes place between metal and polyethylene.

After the first year the results were comparable to those obtained with the Ring arthroplasty (Hansen 1975), and compared to the Ring operation the need for blood transfusion was diminished to about half.

The follow up has been continued with regular x-ray examinations and clinical evaluation. This has revealed that the satisfying primary results are not long-lasting in many cases. So we find it mandatory to publish this report in order to warn against the use of the short stemmed type of prosthesis although the observation period is still quite short. We are aware that the Monk prosthesis is in wide-spread use, but we have not been able to find any other publication on this subject.

PATIENTS AND METHODS

In the period from February 1974 to September 1975 104 Monk arthroplasties were performed on 94 patients. One patient moved to another county and could not be followed up. Eight patients died in the follow up period. Ninety five arthroplasties in 84 patients remained for final evaluation. 45 were women.

Out of 10 bilateral operations five were done in one stage. Two other patients had a Ring total hip on the other side. Symptoms had lasted on an average 7 years. Seventy one of the operations were performed on patients over the age of 60 years and 31 operations on patients over 70 years. The age distribution is shown in figure 1.

55 operations were performed for recent femoral neck fractures. Fifty four had osteoarthritis, ten rheumatoid arthritis and two

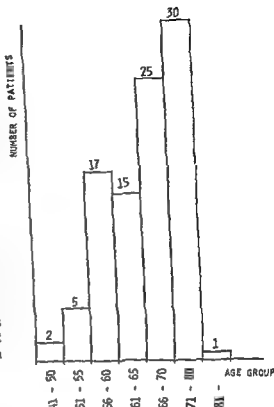


Figure 1 Age distribution of patients having hip operations (52 women, 42 men)

sen & Holstein 1975). In 37 cases the acetabular bed was prepared with a spherical reamer of the same size as the prosthetic cup. In six cases a completely new acetabular bed was prepared with the reamer because of marked deformation of the ream on. In fresh femoral neck fractures no reaming was done.

In five instances adductor longus tenotomy was performed percutaneously. No systemic antibiotics were used but in 64 operations the wound was irrigated with nebacetin containing saline solution. No routine anticoagulants have been used.

In all cases presented in this material the rather short stemmed standard Monk prosthesis was used. The fixation has in all cases been mechanical. No cement was used.

On the second postoperative day the patients were allowed to sit in a chair and they started full weight bearing 10-12 days after surgery.

The observation time has been from 1 year to 2½ years, on average 1.6 years.

been intolerable pain in the hip. In 37 cases there have been other major illnesses with an influence on the walking ability.

The operative procedure was the same as we have used for the Moore arthroplasty with some small modifications ("southern approach") (Jen

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Figure 3 Circular lines of wear on the polyethylene cup of a prosthesis removed after 1 year



Figure 4 Severe wear of a cup removed after 2 years

ments include the eight re-operated cases before the revision.

At the final follow up the patients were asked for their opinion. Accordingly 72 cases (= 76 per cent) were classified as excellent 10 (= 10.5 per cent) as improved and 13 (= 13.5 per cent) as unchanged. In no case was the condition considered to be deteriorated after the operation.

The prostheses removed all had some kind of wear visible on the polyethylene cup, some of them demonstrating that some movement must have taken place between the cup and the acetabulum.

Figures 3 and 4). So far we have not seen any migration of the prosthetic head into the pelvic bone, but in one case with very severe wear on the polyethylene cup.

Figure 4) there was a massive foreign body reaction in the surrounding tissues.

DISCUSSION

After only 1 year of experience with the standard Monk prosthesis we were optimistic about the results (Hansen 1975). However, a longer observation period has revealed that 8 out of 90 hips required revision and furthermore the condition in a few other cases is deteriorating.

The main reason is osteolysis with loosening of the femoral stem. Considering the development of the Moore and Ring prostheses, where longer stems are now available, it seems obvious that the femoral stem of the standard Monk prosthesis is too short to secure a stable fixation. Furthermore, the neck of the Monk prosthesis has too great a varus inclination, resulting in a strong tilting force which a short stem especially is unable to counteract. As shown in Figure 5, the short Ring prosthesis has a better

RESULTS

Mortality Two patients died because of pulmonary embolism, one 16 days, and the other 17 days, after surgery. Both were suffering from complicating illnesses preoperatively. A third patient, an 87-year-old female with a femoral neck fracture and severe heart disease, died 2 months postoperatively. Five other patients died 6 to 26 months after the operation from diseases unrelated to the operation.

Local complications at surgery Two minor fractures occurred, one in the trochanteric region and one in the neck of the femur. Full weightbearing was delayed 4 and 6 weeks in these cases. Otherwise the fractures had no influence on the postoperative course. In one case a spiral fracture occurred in the femoral shaft during the attempt to disarticulate the femoral head. This fracture was treated immediately with osteosynthesis, and weightbearing had to be delayed 8 weeks.

There has been no dislocation postoperatively.

Superficial wound infection occurred in three cases, which all healed, one after debridement and re-suture. No deep infections were detected.

Besides the two fatal pulmonary embolisms there have been five thrombo-embolic complications which all responded well to treatment with anticoagulants and there have been no sequelae.

Osteolysis seems to be the main problem. We have seen 20 cases, three without symptoms. In nine cases the osteolysis was associated with pain during walking. The lower tip of the femoral stem invaded the lateral cortex of femur in three of these (Figure 2). In one the symptoms are so severe that revision may be the end-result. In eight cases with no improvement a revision has already been performed. In one with a Ring arthroplasty, in four with a cemented



Figure 2 The standard Moni prosthesis in a case needing revision. The prosthesis has tilted the tip of the femoral stem has invaded the lateral cortex and there has been considerable resorption of the calcar.

Monk prosthesis and in three cases the prosthesis was removed. At revision no positive cultures for bacteria were found yet one of the Girdlestone hips still has a fistula.

The overall results have been classified according to the code given by Merle d'Aubigné & Postel (1954). In this code score points for pain, movement and walking are recorded. "0" stands for a very poor condition and "6" for a normal condition.

The score points for pain improved from 16 before the operation to 51 after, for movement from 35 to 52 and for walking from 26 to 40. These assess-



Figure 3 Circular lines of wear on the polyethylene cup of a prosthesis removed after 1 year



Figure 4 Severe wear of a cup removed after 2 years

ments include the eight \equiv operated cases before the revision

At the final follow up the patients were asked for their opinion. Accordingly, 72 cases (\equiv 76 per cent) were classified as excellent 10 (\equiv 10.5 per cent) as improved and 13 (\equiv 13.5 per cent) as unchanged. In no case was the condition considered to be deteriorated after the operation.

The prostheses removed all had some kind of wear visible on the polyethylene cup, some of them demonstrating that some movement must have taken place between the cup and the acetabulum (Figures 3 and 4). So far we have not seen any migration of the prosthetic head into the pelvic bone, but in one case with very severe wear on the polyethylene cup (Figure 4) there was a massive foreign body reaction in the surrounding tissues.

DISCUSSION

After only 1 year of experience with the standard Monk prosthesis we were optimistic about the results (Hansen 1975). However, a longer observation period has revealed that 8 out of 95 hips required revision, and furthermore the condition in a few other cases is deteriorating.

The main reason is osteolysis with loosening of the femoral stem. Considering the development of the Moore and Ring prostheses, where longer stems are now available, it seems obvious that the femoral stem of the standard Monk prosthesis is too short to secure a stable fixation. Furthermore the neck of the Monk prosthesis has too great a varus inclination resulting in a strong tilting force which a short stem especially is unable to counteract. As shown in Figure 5, the short Ring prosthesis has a better



Figure 5 The short Ring prosthesis has the neck in a valgus position in contrast to the standard Monk prosthesis giving a direct transmission of the load and a weak tilting force on the femoral component



Figure 6 The Monk prosthesis with a Thompson stem for fixation with cement transmits the forces more directly than the standard type

design. Also the Monk prosthesis with a Thompson stem for cementing has a better design than the standard type (Figure 6). As stressed by Brunelli (1977) this "medialization" diminishes muscular contracture and forcing of the stem onto the lateral cortex of the femur.

The problem of wear of the polyethylene has previously been reported by several authors. Especially the Oscobal prosthesis has shown severe wear after a very short time, probably because this construction necessitates a great deal of movement between the polyethylene cup and the acetabulum (Dahl & Mikkelsen 1976).

In the Christiansen replacement system with trunnion bearing it has been necessary to give the polyethylene a metal cover (Christiansen 1974). Recently the Monk prosthesis has been available with a similar metal cover. This may possibly lead to an increased risk of migration into the acetabulum as has been seen with the Moore prosthesis in some cases. Because of the rather small movements between the cup and the acetabulum this risk is not considered to be very high.

Although many of the problems regarding the use of acrylic cement seem largely to have been solved, many efforts

are still being made all over the world to develop better uncemented types of hip prostheses. In the United States the Gilberty prosthesis utilizes exactly the same bipolar principle as the Monk prosthesis. The Sivash prosthesis can be fixed either with or without cement (Radulovic et al 1972). In Switzerland Mathys has developed an iso-elastic plastic material which works well in finger joint prostheses but is too weak for hip reconstruction as yet (Mathys 1973). The new total Judet prosthesis utilizes a very rough surface for fixation into the bone. It still remains to be proved which principle is the best.

The advantages of the Monk prosthesis are the comparatively atraumatic operative procedure (very similar to the insertion of the well known Moore prosthesis), the short recovery period after the operation and the quite good possibilities for revision should this be found necessary.

However the results must be long lasting and comparable to other types of prostheses and according to our results we cannot recommend the standard Monk prosthesis.

We have therefore changed to the new Monk prosthesis with a long straight femoral stem like the Ring and Moore prostheses and a metal covering on the polyethylene as used in the Christiansen prosthesis. Time will tell if this construction solves the mechanical problems

or if in addition the neck has to be made shorter and with a greater valgus inclination as in the design by Brunelli (1977).

REFERENCES

- Brunelli G (1977) A new square contoured acetabulum and straight stem hip replacement *Int Orthop* 1 36-38
- Christiansen T (1974) A combined endo and total hip prosthesis with trunnion bearing *Acta chir scand* 140 185-188
- Dahl E & Mikkelsen Otto A (1976) Wear of the polyethylene head of the Osceola prosthesis *Acta orthop scand* 47 643-647
- Hansen F Wang (1975) The first years experience with the Monk prosthesis. Proceedings of the Danish Orthopaedic Society *Acta orthop scand* 46 867
- Jensen J Steen & Holstein P (1978) A long term follow up of Moore arthroplasty in femoral neck fractures *Acta orthop scand* 48 764-774
- Mathys R (1973) Current use of plastics in artificial joints *Aktuel traumatologie* 4 3-7
- Merle d'Aubigné R & Postel M (1954) Functional results of the hip arthroplasty with acrylic prosthesis *J Bone Jt Surg* 36 A 451
- Paaby H (1974) Follow up of results from 11 orthopaedic departments of 400 cases of hip arthrosis treated with Ring's total plastic. Proceedings of the Danish Orthopaedic Society *Acta orthop scand* 45 798
- Radulovic M, Kenig I & Radovanovic M (1972) Indications for Sivash type total hip prosthesis: one piece "block" prosthesis. *Arthroplasty of the hip* ed Chapchal G pp 74-79 Georg Thieme Stuttgart
- Ring P A (1974) Total replacement of the hip joint *J Bone Jt Surg* 56-B 44-58

PARA-ARTICULAR OSSIFICATION FOLLOWING HIP REPLACEMENT

70 Arthroplasties ad modum Moore using McFarland's Approach

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Seventy patients representing all the survivors from a group of 117 consecutive Moore arthroplasties were examined 2 years after the operation. A high incidence of para-articular ossification was observed. The ossification was associated with impaired function of the hip joint. The separation of periosteum and fascia from the greater trochanter in McFarland's approach may be responsible for the high incidence of bone formation. This theory is compatible with experimental evidence.

Key words: myositis ossificans, femoral neck fracture, Moore prosthesis.

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Arthroplastic operations on the hip may be followed by characteristic bone formation in the periarticular tissue. One month after the operation these changes are seen on the X-ray film as a faint shadow which, in a few months, grows more intense and assumes a trabecular structure.

Interest in this problem has been revived by the increasing use of hip replacement, but the cause of the bone formation is not understood. The reported incidence of this complication varies widely, and there is disagreement regarding the significance of the para-articular bone in hip function.

In Department 9 of the Copenhagen Municipal Hospital we have found ossification to be common after hip replacement. Therefore, we have performed a follow-up examination of all the available patients subjected to this operation during a specified 2-year period, in order

to elucidate the incidence and classify the calcification. We also studied its influence upon the final result and tried to clarify the aetiology.

PATIENTS AND METHODS

During the 2 year period from 1.4.1969 to 31.3.1971 a total of 117 hip replacement operations were performed according to Moore (1957).

One hundred and twelve operations were primary treatment of a recent medial fracture of the femoral neck. Sixty seven patients had the operation within 24 hours of fracture whereas in 45 patients the operation was deferred because of associated diseases, for 2-35 days (mean 8 days) and temporary traction was used in the intervening period.

Five operations were performed as a secondary measure after failure of osteosynthesis or conservative treatment of medial fractures of the femoral neck.

At all the operations the approach was the McFarland-Osborne (1954) anterolateral incision detaching the insertion of the gluteus medius muscle from the greater trochanter in continuity.

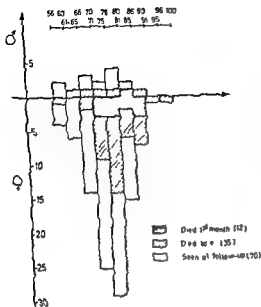


Figure 1 Age and sex distribution of 117 patients

with the origin of the vastus lateralis muscle. The joint capsule was opened by an L-shaped incision and the femoral head was dislocated anteriorly during external rotation of the femur. After insertion of the prosthesis and reduction

started a day or two after the operation.

Complications

Twelve patients died within the first month after the operation. As shown in Figure 1 these patients were predominantly in the oldest age groups, their mean age being 80.6 years.

Seven patients developed sub fascial infection due to *Staphylococcus aureus*. Two of them died within the first month and another two after 2 and 4 months respectively before the wound had healed. In the remaining three patients with deep infection

the cause of hip pain before the follow up examination

Follow-up

At follow up the patients were questioned regarding pain walking ability and working capacity. The gait was observed, and the patients were subjected to a clinical examination

of both hip joints measuring mobility. A Trendelenburg sign if present, was recorded. Radiographs of the operated hip both anteroposterior and lateral views were taken.

RESULTS

In evaluating hip function we used the system of Merle d'Aubigné & Postel (1954).

Periarticular calcification was assessed as follows on the basis of the radiographs (Rosendahl et al 1972)

- + Faint shadows of minimal extent
- + + Scattered lumps of calcification in the periarticular tissue or small exostoses from the trochanter or acetabulum, of radiopacity approximately the same as that of normal bony tissue
- + + + Widespread calcification with distinctly trabecular structure

Among 70 patients included in the follow-up, we found no calcification in 7, mild calcification (+) in 20, moderate (+ +) in 26 and severe (+ + +) in 17.

Table 1 Degree of calcification as compared with the clinical result in the two groups with the poorest results all patients have calcification

Clinical results	Calcification				Total
	-	+	+ +	+ + +	
Very good	4	3	7	2	16
Good	1	4	1	2	8
Medium	1	6	6	4	17
Fair		2	4	2	8
Poor	-	2	6	5	13
Total	6	17	24	15	62

Table 1 lists the calcification compared with the clinical result. Five patients had to be excluded from this evaluation, as their walking was inhibited by other causes: hemiparesis in two, disseminated sclerosis in one, and severe senility in two. A further three

patients were excluded in whom the poor result was due to removal of the prosthesis because of pain. A relationship between increasing calcifications and poor function is seen.

The calcifications usually occurred in the gluteus medius muscle. The relationship between insufficiency of this muscle, indicated by the presence of Trendelenburg's sign, and the degree of calcification is shown in Table 2. In this table increasing calcification seems to be associated with poorer function.

Table 2 Degree of calcification as compared with the occurrence of Trendelenburg's sign. Increasing calcification is seen to be associated with insufficiency of the abductor function.

Trendelenburg's sign	Calcification				Total
	—	+	++	+++	
Negative	6	8	15	4	33
Positive	0	9	9	11	29
Total	6	17	24	15	62

Table 3 Calcification in eight patients excluded because of functional impairment due to other causes.

Reason for exclusion	Degree of calcification
1 Hemiplegia	—
2 Hemiplegia	+++
3 Senile dementia	++
4 Senile dementia	+++
5 Disseminated sclerosis	+
6 Implant removed	+
7 Implant removed	+
8 Implant removed	++

Table 3 shows the calcification in the eight patients excluded because of functional impairment due to other causes.

Deep or superficial infection had no influence upon the occurrence of calcifications, and there was also no difference between the groups of patients having acute and elective surgery.

DISCUSSION

Periarticular ossification after hip replacement is a kind of posttraumatic myositis ossificans. This is a misnomer as it is not an inflammatory condition but the disease entity is well-known and has been well described, clinically and histologically. It is known that the calcification arises through metaplasia of connective-tissue cells in the peri and endomysium. The process progresses rapidly. As early as 3 or 4 weeks after the trauma the calcific shadow may be discerned on the X-ray film, and biopsy at this time may be misinterpreted as osteosarcoma owing to the numerous mitoses. The true cause of calcification following hip replacement has not been definitely established. In the opinion of Botry & Zimmermann (1969) the growth is elicited by bony splints and bone marrow from the operation. However, careful flushing with saline before seating the prosthesis cannot prevent the calcification. Sarmiento & Grimes (1969) assumed that injury to the acetabular rim was the eliciting factor and tried to prevent calcification by sparing this area during the dissection. However, the great majority of calcifications observed by us have clearly arisen from the trochanteric area. Also the Moore operation, using modest dissection, and the McKee total replacement, with comprehensive dissection at the acetabulum, appear to be followed by the same rate of calcification.

Blunt injury to muscle tissue is the main factor in classical posttraumatic myositis ossificans. This factor presumably contributes to the development of calcification following hip replacement as all approaches to the hip joint involve some injury to muscles by the retractors.

Periarticular calcification has occurred in practically all major series of hip replacement. The incidence is usually stated to be about 10 per cent (Estebar 1971, Patterson & Brown 1972), but

many authors have reported divergent rates with a range as wide as from a few up to about 50 per cent. The explanation is possibly that minor degrees of calcification are apt to be overlooked on the X ray film.

Nollen & Slooff (1973), using a classification almost identical to ours, found calcifications in 53 per cent, which is considerably below our 90 per cent. We employed McFarland & Osborne's incision (1954) which differs from most other approaches to the hip joint in the extensive dissection of the periosteal muscle insertion on the greater trochanter.

Zacchalin & Urist (1964) have demonstrated that detachment of the periosteum is the most reliable method for inducing experimental calcifications, in particular if a distance of a few millimetres is established between the bone and the detached periosteum. In this way they could induce severe calcification in 36 out of 36 rabbits. On the other hand injury to the muscle and periosteum caused no calcification in any rabbit.

In the McFarland approach to the hip joint the strong gluteus medius muscle is reinserted by non absorbable sutures through drill holes to the greater trochanter. When walking exercises are started a short time after the operation the diastasis is apt to occur between the muscle periosteal flap and the bone and it is from this space that the calcification arises. Insufficiency of the reinsertion of the gluteus medius may explain the relationship demonstrated by us between Trendelenburg's sign and bone formation. In this connection however, it must be pointed out that the dissection in McFarland's approach is performed close to the nerve fibres from the superior gluteal nerve which innervate the tensor muscle of the fascia lata. Together with the gluteus medius muscle, this is the most important abductor of the hip joint. There is disagreement about the func-

tional significance of the periarticular calcification following hip replacement. Examples of a poor result in the presence of severe calcification are often mentioned but it is well known that even a very severe calcification is not incompatible with a satisfactory functional result.

From the present study there is indication that calcification around the hip joint following hip replacement is associated with impaired function. The marked impairment of abductor function is of particular importance.

In order to prevent postoperative calcification one should avoid extensive dissection of the periosteum from the bone and abstain from approaches which demand this. Flushing off bony splints and gentle retraction of the muscles must also be assumed to be of importance.

If periarticular ossification develops after a hip replacement operation, treatment should be attempted according to the lines of Bohler (1936) for dealing with classical posttraumatic myositis ossificans.

REFERENCES

- Boitz A & Zimmermann H (1969) Komplikationen bei Totalprothesen der Hüfte. *Arch orthop Unfall Chir* 66 192-200.
- Bohler L (1936) Entstehung, Verhütung und Behandlung der Myositis ossificans traumatica. *Der Chirurg* 8 877-883.
- d'Aubigné H M & Postel M (1954) Functional results of hip arthroplasty with acrylic prosthesis. *J Bone Jt Surg* 36 A 451-475.
- Fftekhar A (1971) Low friction arthroplasty: indications, contraindications and complications. *J Amer med Ass* 218 702-710.
- McFarland H & Osborne G (1954) Approach to the hip. A suggested improvement on Kocher's method. *J Bone Jt Surg* 36 B 364-367.
- Moore A T (1957) The self locking metal hip prosthesis. *J Bone Jt Surg* 39 A 811-827.
- Nollen A J G & Slooff T J J H (1973) Para-articular ossifications after total hip replacement. *Acta orthop scand* 44 230-241.
- Patterson F P & Brown C S (1972) The McFarland total hip replacement. *J Bone Jt Surg* 54-A 257-275.

Rosendahl, S, Christoffersen, J K & Nørgaard, M (1973) Paraarticular ossifications after Moore hip replacement Paper read at the Danish Surgical Society
Sarmiento, A & Grimes, H A (1963) The use of the Austin T Moore vitallium prosthesis in

the treatment of acute fractures and other diseases of the hip *Clin Orthop* 28 120-131
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PROPHYLACTIC ANTIBIOTICS AGAINST EARLY AND LATE DEEP INFECTIONS AFTER TOTAL HIP REPLACEMENTS

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A review with a longer observation period is performed of a previously published double blind investigation of the prophylactic value of cloxacillin against late infections after total hip replacements. In addition a retrospective patient material is examined. The total material consisted of 1065 total hips. 15.4 per cent deep late infections were found in the group without prophylaxis and 2.0 per cent in the one with prophylaxis. The frequency of haematogenous deep infection was estimated to be less than 1 per cent.

Key words: Infection, prophylactic antibiotics, total hip arthroplasty.

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Cumulative experience during recent years has shown that the prophylactic use of antibiotics can substantially reduce the frequency of early postoperative infections after total hip replacements (THR) (Ericson et al 1973, Fogelberg et al 1970, Pavel et al 1974). It is, however, still debatable whether such prophylaxis has any effect on the frequency of so called late infections. Many orthopaedic surgeons are inclined to doubt whether such precautions as performance of the operation in a sterile box or the perioperative and early postoperative use of antibiotics really can prevent infections appearing months or even years after the operation. Recent investigations, however, have produced evidence strongly suggesting such a preventive effect (Ericson et al 1973). But corroboration of such an effect requires extensive investigations of several series followed up

for a long time, especially since some of the late infections may be haematogenous and not due to implantation of bacteria during the operation.

This paper concerns a) a review of a double blind investigation earlier published by Ericson et al (1973), b) estimation of the frequency of deep infection in a 7-year material of THR performed with and without prophylactic antibiotics.

Previous investigation

In 1973, Ericson et al reported a double blind investigation of the prophylactic value of cloxacillin used in association with major operations of the hip. The results as regards the THR can be found in Table 1. The result of a retrospective study was also reported. The investigation showed that cloxacillin had a very good preventive effect on early postoperative infections. However, the follow-

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to another hospital for further examination or treatment. The few patients residing outside the receiving area of the hospital were followed up especially for any infection.

Definition of deep infection

Only patients with positive aerobic culture from fistulae or abscesses or with positive aerobic or anaerobic culture from tissue specimens adjacent to the prosthesis or the surface of the cement are included. Furthermore the patients had pain on weight bearing or during rest, roentgen signs of infection according to Bergstrom et al (1974) (radiolucent zone, scalloping and/or periosteal reaction) and an FSR above 35 mm/1 hour without antibiotic therapy.

RESULTS

Review of the patients in the double blind investigation

As seen in Table 1, two deep, late infections supervened in the cloxacillin group and seven in the placebo group during the 4 years that had elapsed since the preliminary study. The difference between the cloxacillin and the placebo groups is significant. The high frequency of infections in the placebo group may be explained by an epidemic accumulation of infections in Lund during the first half of 1971. The cause of the epidemic is not known.

Retrospective investigation

The distribution of the infected and non infected cases found in both the

double-blind investigation and the retrospective investigation is given in Table 2. The frequency of infection was much lower in the group that had received prophylaxis. The difference is highly significant. The interval between the operation and the review was between 2 and 8½ years in the retrospective study. No serious adverse effects from the cloxacillin were seen during the investigation.

Analysis of the infections that occurred despite prophylaxis

The findings are shown in Table 3. Laboratory studies (ESR, CRP, serum electrophoresis, white blood cell count, differential count and radiographic changes around the prosthesis) proved of little value in tracing the origin of the infection and are therefore not considered here.

Two of the 14 patients belonging to the prophylactic group in Table 2 were excluded from this analysis as it was not quite certain that they had received an adequate prophylaxis.

In Table 3 it can be seen that patients nos 1-4 had early infections appearing already during the healing of the operation wound. Patients nos 5-7 were never symptom free after the operation and had slight pains when walking all the time, but the diagnosis infection was not

Table 2 Distribution of infected and noninfected patients in the two groups with and without prophylaxis

	With prophylaxis		Without prophylaxis		Total
	Not inf	Inf	Not inf	Inf	
Prospective study	58	2	44	14	118
Retrospective study	623	17	267	40	947
Total	681	19	311	54	1065
	(2.0%)		(15.4%)		

$P < 0.001$ (chi square with Yates correction)

Table 1 Incidence of deep, early and late infections in the double blind investigation

	Total	Cloxacillin		Placebo		
		Not inf	Inf	Not inf	Inf	
1-2½ years postoperatively	118	60	0	51	7	($P < 0.05$) *
5-6½ years postoperatively	118	58	2	44	14	($P < 0.01$) *

* chi-square with Yates correction

up was not long enough to warrant any conclusion as to the effect on the frequency of late, deep infections

MATERIAL AND METHODS

Only deep infections, both early and late, were considered. Superficial infections which healed without developing into deep infections were not included.

The material consisted of all 1130 hips (476 in men and 654 in women) operated upon with THIR between 1968 and 1974 in the Department of Orthopaedic Surgery, University Hospital Lund (510 hips) and the Department of Orthopaedic Surgery, Malmö General Hospital, University of Lund Malmö, Sweden (620 hips). The mean age at the time of operation was 64.6 ± 9.3 years (average ± 1 SD). The youngest patient was 10 years and the oldest 87. The patients were reviewed during the first 3 months of 1977 which means between 2 and 9 years after the operation. Sixty-five patients were not included either because it was not possible to ascertain whether prophylaxis had been given or because the patients had not appeared at follow up or review. Patients who had died within 6 months of the operation without having had any known infection were not included in the investigation. All operations were performed in conventional modern operating rooms.

The investigation was divided into

a) a review of the 118 THIR in the previously mentioned double blind investigation of Ericson et al (1973) in which the patients had been examined after a postoperative interval of 1 to 2½ years. In the present review the reexamination was performed 5 to 6½ years postoperatively. In the investigation by Ericson et al both superficial and deep infections were considered. In the present study, only the deep ones were included.

b) a retrospective investigation of the 947 other THIR, 635 had received prophylaxis and 312 had not. 761 were operated according to

Charnley, 183 according to Brunswik and three according to McKee-Tarrar.

Prophylaxis

The antibiotic used was cloxacillin (Lixacilin® Astra Pharmaceutical, Sweden). The patient was given 1 g intramuscularly 1 hour before the operation and thereafter three times at 6-hour intervals. This was followed by two tablets each containing 0.5 g which were taken in the fasting state with a glass of water. The oral dose was given every 6 hours until the fourteenth day inclusive after the operation. In addition the patient received oral probenecid in a dose of two tablets, each 0.5 g, twice a day during the same period as the cloxacillin. In the double-blind investigation the placebo was given in the same way as the active substance. The patients receiving placebo instead of cloxacillin were also given probenecid in the same dose. Patients who found it difficult to take the tablets by mouth were given intramuscular injections. The few patients known to be hypersensitive to penicillin or who developed such hypersensitivity during treatment were given lincomycin or cephalosporin, in corresponding doses, instead of cloxacillin. Since January 1974 the prophylaxis at the Orthopaedic Department in Lund has been shortened to 1 week after the operation.

Review

All patients with any symptoms or roentgen changes at the obligatory final follow up 1 month to 1 year after the operation were re-examined at regular intervals until the cause of the symptoms could be explained or the symptoms had disappeared. It was not difficult to trace the patients with infection because patients operated upon at either of the two departments belonged to the receiving areas of the departments. Therefore according to the Swedish insurance regulations they could not seek advice at any other hospital before they had first been examined at their local hospital where they were registered and if necessary, referred

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Table 3 (continued)

Pat	Onset of symptoms	Time of diagnosis of infection	Bacteria	Sensitive to cloxacillin	Comments
9	4 months postop	After 4 months	Staph aureus	Yes	Aspiration 4 months postop and biopsy 6 months postop gave Staph aureus
10	6 months postop	After 7 months however antibiotics since second month postop because of elevated ESR	Anaerobic streptococci and Gram neg. rods	Not tested for susceptibility	Aspiration from abscess 6 months after op gave growth of anaerobic streptococci. Material obtained on extraction of prosthesis 1 year later gave Gram negative rods. PSN never normalized
11	1 year postop	After 3 years and 2 months	Staph albus	Yes	Culture of two biopsy specimens, both positive. Patient had previously had a Moore prosthesis which was replaced by a total prosthesis
12	2 years and 4 months postop	After 3 years and 4 months	Propionibacteriacnes and Staph albus	Yes	Culture gave growth of Propionibacteriacnes and Staph albus from biopsy specimen. Staph albus alone at extraction of prosthesis

made until after 2-3 years thus called late. The patients nos 8-10 probably belonged to the same group but here nothing abnormal had been entered in the patients record. Patients 11 and 12 were quite symptom free during 1 1/2 years postoperatively.

In seven cases the infection was caused by microbes sensitive to cloxacillin in spite of the fact that this antibiotic was given prophylactically.

DISCUSSION

It has been clearly shown that antibiotic prophylaxis can substantially reduce the frequency of early infection after THR (Ericson et al 1973, Fogelberg et al 1970, Pavel et al 1974). Yet it is still debatable whether such prophylaxis can prevent so-called late infections. That prophylaxis with cloxacillin has a good preventive effect against late infections around THR caused by the bacteriological flora existing at the two above-mentioned hospitals is however clear from the results of this investigation.

The very high frequencies of post-

Table 3 Analysis of infected patients who had received prophylaxis

Pat	Onset of symptoms	Time of diagnosis of infection	Bacteria	Sensitive to cloxacillin	Comments
1	Immediately postop	Immediate deep infection after op	Proteus and enterococci	No	Immediate postop inf Culture of biopsy specimen
2	Immediately postop	Immediate deep infection after op	Proteus and Staph albus	No	Immediate postop inf Both proteus and Staph albus in each of six specimens taken from the tissue adjacent to prosthesis during extraction
3	Immediately postop	Immediate deep infection after op	E coli	No	Immediate postop inf Prosthesis extracted Repeated cultures from abscess gave abundant E coli
4	Immediately postop	Immediate postop infection	Anaerobic peptococci and anaerobic streptococci	Yes	The inf was in the beginning successfully treated with antibiotic, but prosthesis extracted after 2½ years Culture of biopsy specimen at extraction
5	Never quite symptom free	After 2 years 4 months	Propionibacteres	Yes	Culture of six biopsy specimens positive at extraction of prosthesis Bilat op, other side not infected Reported clear difference between sides, became immediately symptom free in the uninfected hip
6	Never quite symptom free	After 2 years 7 months	Propionibacteres	Yes	Culture of biopsy specimen from joint capsule positive Bilat op Other side not inf Reported clear difference between sides became immediately symptom free in the uninfected hip
7	Never quite symptom-free	After 3 years 4 months	Staph aureus	Yes	Culture of biopsy specimen positive at extraction of prosthesis Bilat op Reported clear difference between sides, became immediately symptom free in the uninfected hip TSR never normalized
8	3 months postop	After 6 months	Pseudomonas pyocyanea	No	July 1972 postop inf with pseudomonas pyocyanea after nailing of fracture of femoral neck Jan 1973 total arthroplasty 6 months postop fistula with pseudomonas pyocyanea ESR never normalized

PERTHES' DISEASE

A Study of Radiological Features

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A study is presented of the radiographs of 68 patients with unilateral Perthes disease. Two types of Perthes disease are identified: fragmenting and non fragmenting. The two radiological types of the disease showed no significant differences in the age at diagnosis, the duration of symptoms before diagnosis and the duration of the disease. However, the radiologically measurable results at healing, in terms of the epiphyseal acetabular acetabulum head and comprehensive quotients were all very significantly worse when fragmentation had developed.

Key words: femoral head fragmentation, Perthes disease.

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The radiological features of Perthes disease have been studied extensively since its first description in 1910 (Jegg Calve, Perthes). Waldenström (1922) described the typical radiological changes of the condition which included a stage during which the femoral head appeared to fragment. Rathff (1936) and Somerville (1971) noted that fragmentation of the femoral capital epiphysis did not always occur in Perthes disease and that in such patients the shape of the femoral head at the time of healing was perfect. On the basis of antero-posterior and lateral radiographs taken at onset, Waldenström (1938), Fèvre (1955) and Garra (1969) classified the disease according to whether the whole, or only part of the femoral head appeared to be involved; they related the extent of involvement to the prognosis. Catterall

(1971) described four different forms of Perthes' disease according to the amount of the femoral capital epiphysis affected by the disease as seen on the radiographs obtained at the time of diagnosis. Hamhi & McEwen (1975) stated that Catterall's classification could not be applied until the disease had progressed to the stage of fragmentation. Katz (1973) divided patients with Perthes' disease into three different groups, depending on the amount of the femoral epiphysis that appeared to fragment accordingly his classification can be applied only at a late stage of the disease.

This paper reports a study of the radiographs of 68 patients with unilateral Perthes' disease, from diagnosis to healing. Some 46 patients showed radiological evidence of fragmentation of the femoral capital epiphysis.

operative infection reported from different parts of the world during the first years when total hip replacements were performed has now been considerably lowered through rigorous asepsis, e.g. clean-air operating room enclosures or through the prophylactic use of antibiotics. In this investigation the frequency has been lowered from 15.4 to 2.0 per cent with the use of antibiotics alone. This reduction must depend on a decrease in the number of infections caused by implantation of bacteria during the operation. Otherwise it is difficult to explain why this measure taken at the operation and during the following 1-2 weeks should have an effect for several years.

If this argument is correct, haematogenous infections are to be found among those infections which occur despite the use of prophylactic antibiotics (Table 3). Patients nos 1-4 had early infections and were thus most probably infected during the operation. Patients nos 5-7 were never pain-free which otherwise is the rule after a successful THR. In patients 7, 8 and 12 preoperatively low ESR was never restored after the operation which indicates that all these five patients (5, 6, 7, 8, 12) were infected during the operation (Reichelt & Brand 1975). An argument against this is that patients 5-7 were infected with microbes sensitive to cloxacillin.

In the remaining two patients (10, 11) there is nothing to specially indicate postoperative infection. The long symptom-free interval in patient 11 rather indicates that the infection was haematogenous. In the patient group without prophylaxis three patients (0.8 per cent) seemed to have haematogenous infections, two in association with sepsis caused by pneumococci. The third patient had bilateral THR and suffered sudden pains in both hips after 3 years

without symptoms and *Staphylococcus aureus* was found in both hips.

This means that the frequency of haematogenous infections in this material was well under 1 per cent which is in agreement with the figures given by Charnley (1972), 0.30 per cent, and Arl et al (1975), 0.25 per cent.

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REFERENCES

- Artz, T., Maces, J., Salvati I., Jacobs B. & Wilson W. (1975) Haematogenous infection of total hip replacements. A report of four cases. Report at the 32nd annual meeting of The American Academy of Orthopaedic Surgeons.
- Bergstrom B., Lidgren I. & Lindberg L. (1974) Radiographic abnormalities caused by postoperative infections following total hip arthroplasty. *Clin Orthop* 99: 94-102.
- Charnley, J. & Ffitch, N. (1969) Postoperative infections in total prosthetic replacement arthroplasty of the hip joint with special reference to the bacterial content of the air of the operating room. *Brit J Surg* 56: 641.
- Charnley, J. (1972) Postoperative infection after total hip replacement with special reference to air contamination in the operating room. *Clin Orthop* 87: 167-187.
- Lidgren C., Lidgren I. & Lindberg L. (1973) Cloxacillin in the prophylaxis of postoperative infections of the hip (with Addendum). *J Bone Jt Surg* 55A: 808-813.
- Logelberg E., Vitzmann F. G. & Stinchfield I. I. (1970) Prophylactic penicillin in orthopaedic surgery. *J Bone Jt Surg* 52A: 95-98.
- Kamme C., Lidgren I., Lindberg L. & Mårdh P. A. (1974) Anaerobic bacteria in late infections after total hip arthroplasty. *Scand J Infect Dis* 11: 161-165.
- Pavel A., Smith R., Ballard A. & Larsen I. (1974) Prophylactic antibiotics in clean orthopaedic surgery. *J Bone Jt Surg* 56A: 777-781.
- Reichelt A. & Brand A. (1975) Das Verhalten der Blutsenkungsgeschwindigkeit nach der Implantation von Totalendoprothesen des Hüftgelenkes. *Z Orthop* 113: 900-903.

Table 1 Forty six patients with the fragmenting type of unilateral Perthes disease

Initials	Age at diagnosis (years)	Length of history (weeks)	Length of disease (years)	Radiological assessment			
				FQ	AQ	AIQ	CQ
I H +	3	½	3	45 C	103.6	91.1	80.1
V H +	4	20	3	58.1	93.8	65.1	72.3
K J +	5	6	2	71.3	87.4	84.3	83.0
B T +	5	½	4	63.8	102.0	100.9	88.9
A D +	6	52	4	35.1	86.2	87.9	76.4
J A +	6	3	4	64.7	83.8	91.4	79.9
B I +	6	2	2	31.2	105.8	104.4	87.1
W C +	8	4	3	65.1	95.5	100.8	88.1
P G	8	10	3	69.9	112.8	100.0	94.2
K O	3	½	5	81.1	79.9	95.5	87.7
H P	3	4	4	71.4	96.6	85.4	84.5
J I	3	1	3	58.3	82.9	123.2	88.1
D W	3	1	2	87.2	87.9	86.8	87.2
I B	4	26	2	79.4	40.4	98.2	86.0
H J	4	8	3	91.6	85.2	98.0	91.6
G S	4	6	5	91.2	100.0	86.5	92.6
B T	4	32	8	51.3	80.2	80.5	70.8
D W	4	12	3	68.3	45.8	92.8	69.3
J J	5	½	1	66.3	63.2	100.9	76.8
M J	5	½	2	87.7	89.3	107.8	95.6
I W	5	13	2	61.3	102.3	102.8	88.8
P W	5	1	2	66.1	86.9	85.7	79.8
D P	5	23	2	78.4	63.6	86.2	78.1
P H	5	4	3	40.8	60.6	71.1	57.5
J W	5	½	2	59.9	94.1	84.2	79.4
S W	5	1	3	79.7	113.8	98.2	97.2
P B	6	2	4	49.4	100.7	91.9	80.7
K D	6	8	3	69.2	88.3	90.6	82.7
L L	6	3	3	67.6	83.1	95.0	81.9
A S	6	½	2	65.1	90.5	94.7	83.5
M S	6	4	4	72.7	80.8	64.6	72.7
H T	6	½	4	63.1	93.6	109.2	83.0
I W	6	0	2	72.8	114.0	94.0	93.6
P W	6	8	4	76.2	71.9	91.3	79.8
P B	7	4	3	45.7	63.9	67.6	60.1
A H	7	1	4	72.3	90.0	79.1	80.5
K H	7	5	2	64.4	72.0	93.2	76.6
B I	7	52	2	83.0	90.1	75.9	83.0
D W	7	½	2	66.0	94.6	95.1	85.3
K H	8	½	2	87.0	76.0	93.4	85.5
A T	8	4	3	65.9	96.8	95.0	80.9
H B	9	½	2	72.3	65.0	79.6	72.3
D B	9	2	2	71.1	82.4	84.5	79.3
A S	9	3	3	54.9	87.7	93.3	77.3
K B	10	½	1	60.6	67.3	89.7	72.5
H W	10	6	4	39.1	112.2	97.7	83.1
Mean	5.7	10.0	2.9	67.4	87.0	91.0	81.5

+ girls
 ½ not known
 0 less than one week

See text for radiological assessment abbreviations

PATIENTS AND METHODS

Patients The children in this study had been treated as in patients at three orthopaedic hospitals (The Marguerite Hepton Orthopaedic Hospital, Thorp Arch Wetherby, The Woodlands Orthopaedic Hospital, Bradford, The Children's Hospital, Nottingham) during the years 1944 to 1970. The methods used for treatment included traction, Thomas' splint, rest on Jones' abduction frame, hip-spica, broomstick plasters and patten ended calipers. None of the patients had been treated by surgery. Selection of the radiographs depended on the availability of antero-posterior and lateral views. Patients with bilateral disease were excluded because of the difficulty of assessing the radiological findings when no unaffected contralateral femur was available to act as a control. Of the 68 patients, 55 were boys and 13 girls.

Radiological assessments The serial radiographs for each patient were examined and judged as to whether or not fragmentation had occurred in the femoral capital epiphysis during the natural history of the disease. The epiphysis was considered to have fragmented if a part, or the whole, of the bony nucleus showed the development of one or more separate fragments within, or at the periphery of, the nucleus. Healing was considered to have occurred when the radiological density throughout the femoral capital epiphysis, femoral neck and pelvis had returned to that observed in the opposite hip.

At healing each hip was assessed quantitatively using the techniques of Heyman & Hernon (1950). The following quotients were measured: the epiphyseal (LQ), the acetabular (AQ) and the acetabulum head (AHQ), the mean of these quotients was called the comprehensive quotient' (CQ).

Statistical analysis After categorizing the patients according to whether or not fragmentation had occurred t-tests were performed for each of these quotients, EQ, AQ, AHQ and CQ. Similar tests were carried out for the two radiological types of the disease with respect to the age at diagnosis and the duration of the disease from diagnosis to healing. Further statistical analyses were undertaken to find whether the outcome of the disease was influenced by the sex of the patient, or the age at diagnosis (2-4 years and over 5 years).

RESULTS

In 46 patients (38 boys and 8 girls) the femoral capital epiphysis had undergone fragmentation. In 22 patients (17 boys

and 5 girls), the femoral capital epiphysis showed areas of increased and decreased density, irregularity of the outline of the bone nucleus, but no separate fragments. Examples of each radiological type during the active phase of the disease are shown in Figures 1 and 2.

The age at diagnosis, the duration of symptoms, the duration of the disease from diagnosis to healing and the results of the radiological assessments are summarized for the two types of the disease in Tables 1 and 2.

The radiographs of the 46 children with fragmentation often showed changes in the metaphysis and occasionally in the acetabulum (Figure 3). The AQ (Table 1, mean 87.0) and the AHQ (Table 1, mean 91.0) suggested that lasting damage to acetabulum had occurred. Moreover, the femoral head was markedly affected after fragmentation (Table 1, mean EQ 67.4).

The radiographs of the 22 children with the non-fragmenting type of disease showed, despite the whole head involvement, that the end results were satisfactory. Metaphyseal changes, with an increase in the 'teardrop-distance' (Firing et al 1965), were frequently seen in the radiographs of these children (Figure 4). In this type of the disease only the capital femoral epiphysis showed lasting effects after the disease had healed (Table 2, mean EQ 84.9). The acetabulum showed little sign of damage (Table 2, mean AQ 98.7) and the femoral head remained well covered by the acetabulum (Table 2, mean AHQ 97.7). The outcome of Perthes' disease of the non-fragmenting type was very satisfactory at healing (Table 2, mean CQ 93.8).

Differences between the findings for fragmenting and non-fragmenting hips are highly significant (Table 3).

The radiographs obtained at an early stage did not distinguish between the two radiological types (Figures 1 and 2).

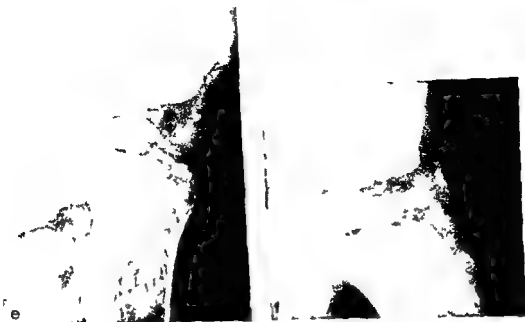


Figure 1 e f 11 months after diagnosis. Fragmentation continues. head within the head apparent



Only later (from 4 to 18 months) did it become apparent which of the disease types was present. Once fragmentation is evident Catterall's (1971) or Katz's (1973) classification can be used to assess the prognosis.

Tables 4 and 5 show there is no statistically significant difference between the two types of the disease with respect to the age at diagnosis, the duration of symptoms before diagnosis and the duration of the disease. Table 5 shows that the sex of the patient did not appear to influence the results as judged radiologically. Also the duration of the disease in boys was similar to that in girls for both types of the disease. Table 6 shows that when we compare the radiological quotients in early onset patients (2-4 years) with those for late-onset patients (6 years and above) the former enjoy on the average a slightly better result than late onset patients although only in two comparisons does the difference achieve conventional levels of significance.

Figure 1 g 37 months after diagnosis. Healed. Perthes disease. FQ 487 AQ 63.9 AHQ 67.6 Q 60.1



Figure 1 a b PB 7 year old boy Duration of symptoms 4 weeks Radiographs taken when the diagnosis was made



Figure 1 c d Radiographs taken 7 months after diagnosis Fragmentation of the distal radius is evident Metaphyseal changes are present (Gatterall Group III)



Figure 1 e f 11 months after diagnosis Fragmentation continues head within the head apparent



Figure 1 g 37 months after diagnosis Healed
Perthes disease EQ 587 IQ 639 AHQ 676
IQ 601

Only later (from 4 to 18 months) did it become apparent which of the disease types was present. Once fragmentation is evident, Catterall's (1971) or Reitz's (1973) classification can be used to assess the prognosis.

Tables 4 and 5 show there is no statistically significant difference between the two types of the disease with respect to the age at diagnosis, the duration of symptoms before diagnosis and the duration of the disease. Table 5 shows that the sex of the patient did not appear to influence the results as judged radiologically. Also, the duration of the disease in boys was similar to that in girls for both types of the disease. Table 6 shows that when we compare the radiological quotients in early onset patients (2-4 years) with those for late-onset patients (6 years and above), the former enjoy, on the average, a slightly better result than late-onset patients although only in two comparisons does the difference achieve conventional levels of significance.

Table 2 Twenty two patients with the non fragmenting type of unilateral Perthes disease

Initials	Age at diagnosis (years)	Length of history (weeks)	Length of disease (years)	Radiological assessment			
				IQ	AQ	AHQ	CQ
JA +	3	Nk	3	68.4	118.4	103.1	96.6
LS +	5	Nk	2	91.2	100.0	102.6	97.9
TD +	6	5	2	75.1	95.9	94.2	89.4
VR +	6	Nk	3	81.7	105.0	88.7	92.8
SG +	6	1	2	83.3	100.4	95.9	93.2
GS	2	1	5	100.0	101.8	99.2	100.0
JB	3	3	1	88.8	87.6	90.0	88.8
SC	3	Nk	2	72.6	90.1	88.4	83.7
CM	3	Nk	2	100.0	98.4	106.3	101.5
PW	3	6	4	84.4	86.9	112.6	94.6
SB	4	1	1	91.0	100.0	93.3	94.8
SF	4	12	3	82.7	102.6	110.3	98.5
JP	4	1	4	102.6	100.0	88.7	97.1
LW	4	1	3	100.0	115.3	91.9	102.4
TD	5	2	2	80.4	100.0	109.1	96.5
JP	5	Nk	2	76.2	104.0	103.4	94.5
MW	5	0	2	93.6	85.9	106.9	95.5
AB	6	6	3	78.3	96.6	91.4	88.1
DH	6	37	2	94.0	96.9	91.1	94.0
PB	7	8	1	70.7	98.4	100.0	89.7
MH	8	8	3	67.6	92.7	92.9	84.4
KT	10	6	3	81.7	95.4	89.8	88.9
Mean	4.9	6.1	2.45	84.9	98.7	97.7	93.8

+ = girls

Nk = not known

0 = less than one week

See text for radiological assessment abbreviations

Table 3 Radiological quotients EQ AQ AHQ and CQ in fragmenting and non fragmenting types of unilateral Perthes disease

Radiological quotients	Groups tested (null hypothesis)				P
	Non fragmenting versus fragmenting				
	(n = 22)		(n = 46)		
	Mean	Standard deviation	Mean	Standard deviation	
EQ	84.9	10.7	67.4	13.0	$< 8 \times 10^{-7}$
AQ	98.7	8.0	87.0	15.3	$< 9 \times 10^{-5}$
AHQ	97.7	7.9	91.0	11.4	$< 7 \times 10^{-3}$
CQ	93.8	5.1	81.8	8.4	$< 8 \times 10^{-10}$

* t test 1 tailed equal variance

† t test 2 tailed unequal variance



Figure 2 a b PW 3 year old boy Duration of symptoms 6 weeks Radiographs taken when the diagnosis was made Changes in the metaphysis evident

Table 3 Results of miscellaneous statistical tests

Parameter compared	Non fragmenting			Fragmenting			p
	Mean	SD	n	Mean	SD	n	
Age at diagnosis	4.91 years	1.90 years	III	5.74 years	1.89 years	46	0.096
Duration of history	6.12 weeks	8.90 weeks	22	10.03 weeks	13.0 weeks	46	0.23
Duration of disease	2.45 years	1.01 years	22	2.87 years	1.17 years	46	0.16 *
Duration of disease boys	2.47 years	0.55 years	17	2.87 years	1.23 years	39	0.89 *
Duration of disease girls	2.40 years	1.12 years	5				
Duration of disease boys						8	0.50
Duration of disease girls							
Duration of disease age at diag < 4 years	2.70 years	1.34 years	III	3.50 years	1.01 years		0.50 *
Duration of disease age at diag 4 years and above	2.34 years	0.74 years	8				
Duration of disease age at diag < 4 years							0.14 †
Duration of disease age at diag 4 years and above							
				2.75 years	0.99 years		

† 1 to 1.2 tailed equal variance

† 1 test 2 tailed on equal variance



Figure 2 c d Radiographs taken 7 months after diagnosis. Irregularities in the density and outline of the capital epiphysis but no separate fragment can be identified.



Figure 2 e f Radiographs taken 1 1/2 months after diagnosis. The radiological density of the capital epiphysis is still irregular but there is no fragmentation.

9

Figure 2 g 48 months after diagnosis Healed
Perthes disease FQ 836 AQ 869 AHQ 1126
EQ 916

Figure 3 PR 5 year old boy at the time of
diagnosis of Perthes disease This radiograph
was taken 18 months after diagnosis and shows
changes in the acetabulum in addition to the
fragmentation of the capital epiphysis

Table 5 Radiological quotients in girls compared with those in boys for fragmenting and non fragmenting types of Perthes disease

Radiological quotients	Girls			Boys			P *
	Mean	S D	n	Mean	S D	n	
<i>Not fragmenting</i>							
FQ	80.5	8.9	5	86.2	11.1	17	0.32
AQ	103.9	8.7	5	97.2	7.3	17	0.037
AHQ	96.9	6.1	5	97.9	8.5	17	0.81
EQ	93.8	3.7	5	93.7	5.6	17	0.99
<i>Fragmenting</i>							
FQ	60.1	9.8	8	69.0	13.2	38	0.080
AQ	95.1	8.6	8	85.3	15.9	33	0.099
AHQ	90.7	12.5	8	91.0	11.3	33	0.95
EQ	82.0	5.9	8	81.8	8.9	38	0.95

* t test assuming equal variance

Table II Radiological quotients in patients with the onset at 2 to 4 years compared with those in patients with the onset at 6 years and above

Radiological quotients	Type	Groups tested (null hypothesis)						P
		Early onset			Late onset			
		Mean	S D	n	Mean	S D	n	
IQ	Non frag	89.0	12.0	10	79.4	8.4	8	* 0.074
	Frag	71.8	15.9	12	64.9	11.1	24	* 0.014
AQ	Non-frag	100.1	10.6	10	97.7	3.7	8	† 0.51
	Frag	87.4	16.8	12	87.1	13.7	24	* 0.96
AIQ	Non frag	98.3	9.2	10	93.0	3.7	8	† 0.12
	Frag	91.9	13.8	12	90.0	10.5	24	* 0.64
CQ	Non frag	95.8	5.8	10	90.0	3.2	8	* 0.022
	Frag	83.7	8.6	12	80.7	6.9	24	* 0.26

* t test 2 tailed, equal variance

† t test 2 tailed unequal variance



Figure 4 T.D., 5 year-old boy: Duration of symptoms 2 weeks. Radiographs taken at the time of diagnosis. The tear drop distance is increased on the right and the outline of the right capital epiphysis is irregular. The femoral neck is broadened and metaphyseal changes are evident. The child developed Perthes' disease of the non fragmenting type.

DISCUSSION

Our radiological study delineates two different types of Perthes' disease. The fact that we found no significant differences between the types in the age at diagnosis, the duration of symptoms and the duration of the disease, suggests that we are observing the same basic disease in its less and more severe forms. We suggest, therefore, that the term 'dysplasia epiphysealis capitis femoris' (Pedersen 1960,

Meyer 1964, Lauritzen 1975) should not be applied to the non-fragmenting type of the disease, we found no evidence to support Meyer's (1964) suggestion that this type of the disease develops in a previously malformed or dysplastic epiphysis.

The difference in the radiological course and the measurable results between the two types of the diseases is very marked. We find that, in the non fragmenting type of disease only the capital epiphysis appears to be lastingly damaged although the whole of the epiphysis is clearly involved. In the fragmenting type, the acetabulum and also the relation of the femoral head to the acetabulum appear to have been disturbed, in addition to the deformity of the femoral capital epiphysis. The acetabular changes as described by the two quotients are perhaps secondary to the pathological process in the femoral head. It seems clear, however, that they occur only when the femoral capital epiphysis fragments.

Within the same type of Perthes' disease, the sex and the age of the patient at diagnosis appear to have little or no effect on the final outcome of the disease, although larger series are needed for definite conclusions.

As this study did not include the radio-

graphs of every child treated for Perthes disease in the three hospitals during the indicated period we can draw no firm conclusions about the relative frequency of occurrence of the two types. We can state however that if the diagnosis is made at an early stage it is not possible to judge from the radiographs which type of the disease will develop. Some 4 to 18 months later it will become clear which type of Perthes disease is affecting the child. If fragmentation fails to appear on the radiographs a relatively good prognosis can be given if fragmentation manifests. Catteralls (1971) or Katz's (1973) classification helps to forecast the final results of the disease.

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REFERENCES

- Calvé J (1910) Sur une forme particulière de pseudorachisme grave sur des déformations caractéristiques de l'extrémité supérieure du fémur. *Rev. Chir. (Paris)* 42: 34-84.

- Catterall A (1971) The natural history of Perthes disease. *J. Bone Jt. Surg.* 53-B: 37-44.
 Fyring E, J. Björnson D. R. & Peterson C. A. (1962) Early diagnostic and prognostic signs in Legg-Calvé-Perthes disease. *Amer. J. Roentgenol.* 88: 359-387.
 Feys W (1922) Osteochondritis of the hip. *J. Bone Jt. Surg.* 37-B: 513.
 Heyman C. H. & Herndon C. H. (1920) Legg-Perthes disease: A method for the measurement of the roentgenographic results. *J. Bone Jt. Surg.* 32-A: 767-778.
 Hamish P. & MacEwen G. D. (1975) Treatment of Legg-Calvé-Perthes disease. *J. Bone Jt. Surg.* 57-A: 631-654.
 Katz J. F. (1973) Legg-Calvé-Perthes disease: a statistical evaluation of 358 cases. *Ut. State J. Med.* (N.Y.) 40: 20-47.
 Lauritzen J (1975) Legg-Calvé-Perthes disease. *Acta orthop. scand. Suppl.* 159.
 Legg A. T. (1910) An obscure affection of the hip joint. *Boston med. surg. J.* 169: 209-204.
 Meyer J (1964) Dysplasia epiphysealis capitis femoris. *Acta orthop. scand.* 34: 183-197.
 O'Garra J. A. (1959) The radiographic changes in Perthes disease. *J. Bone Jt. Surg.* 41-B: 465-476.
 Pedersen E. K. (1960) Dysplasia epiphysealis capitis femoris. *J. Bone Jt. Surg.* 42-B: 663.
 Perthes H. (1910) Über Arthritis deformans juvenilis. *Dtsch. Z. Chir.* 107: 111-159.
 Rathbun A. R. C. (1926) Pseudorachitis. *J. Bone Jt. Surg.* 50-B: 498-512.
 Somerville F. W. (1971) Perthes disease of the hip. *J. Bone Jt. Surg.* 53-B: 639-649.
 Waldenström H. (1922) The definite form of coxa plana. *Acta radiol. (Stockh.)* 1: 384-394.
 Waldenström H. (1928) The first stages of coxa plana. *J. Bone Jt. Surg.* 20: 559-566.

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ULTIMATE BONY FUSION OF LOWER LIMB JOINTS FOLLOWING SEVERE TRAUMA

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Three patients presented with limb deformity some years after being run over and sustaining degloving injuries of their lower limbs. Spontaneous joint fusions were observed in each patient. The causes of these could be 1) Extensive intra articular fracture, 2) Prolonged immobilisation due to the scar tethering the joint, or most likely 3) A chronic low grade infection following compound joint injury with degloving.

Key words: articular joints, epiphyseal injury, spontaneous fusion trauma

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It is well established that severe crush injuries to an epiphyseal plate will cause it to fuse prematurely and if significant growth potential remains, it will produce a shortened limb. This is the so-called type (v) injury of the epiphyseal plate described by Saller & Harris (1963). Spontaneous fusion of lower limb joints following injury is much less common. The purpose of this paper is to report three cases of this type and to comment on their possible aetiology.

CASE REPORTS

Case 1 A 24 year old male complained of a stiff knee and shortening of the right lower limb. When 8 years old his limb had been run over by a car resulting in an extensive degloving injury of the entire limb and a fracture of the mid shaft of the femur. The details of the initial treatment were not available but it was essentially replacement of the degloved skin and

conservative management of the fractured femur.

On examination 16 years later, there were signs of extensive healed scars over the entire limb. There was bony ankylosis of the knee with 4 cm of limb shortening. Both the ankle and knee joints were fixed in 30° of flexion.

Radiographs confirmed bony fusion of all three compartments of the knee joint in addition to the ankle and subtalar joints (Figures 1, 2 and 3).

Case 2 A 16 year old male had his right foot run over by a car when he was a child aged 8 years. There was no history of a fracture but there had been extensive degloving of the medial aspect of the ankle and foot. Radiographs 8 years later demonstrated fusion of the ankle joint with the lower tibial growth plate intact (Figure 4).

Case 3 A 16 year old female presented with a valgus foot deformity. When aged 7 years her right lower limb had been run over by a bus resulting in a degloving injury.

Radiographs revealed premature fusion of the growth plates at both ends of the fibula with separation of the superior tibio fibular joint. There had been spontaneous fusion of the entire



Figure 1 Case 1 Antero-posterior radiograph of right knee in 31 year old male. Severe degloving injury of limb when aged 8 years. Note that no fusion of the knee joint has occurred in intercondylar notch still visible (n)



Figure 2 Case 1 Lateral radiograph of the same knee showing spontaneous bony fusion of the patello femoral (arrow) and the tibio femoral joints

ankle joint with a valgus ankle yet the lower tibial epiphyseal plate was still visible (Figure 3)

DISCUSSION

All three patients had been run over and sustained severe degloving injuries to their limbs. Although the history of the initial injury was not complete in every instance only in case 1 was a definite history of an associated fracture at the time of injury elicited.

A factor common to all 3 patients was the extent of the soft tissue injury particularly around the joints which finally became fused.

Several possibilities exist to explain this phenomenon of spontaneous joint fusion. If the trauma had produced extensively comminuted intra articular fractures then bone of the adjacent epiphyses would have been brought into contact and this would inevitably have resulted in joint fusion. It is likely that if this were the case, then injury of such magnitude should have damaged in addition the adjacent epiphyseal plates but this did not occur.

Enneking & Horowitz (1972) recently reported the intra articular effects of long periods of immobilisation of ten human knees. Where articular cartilage had been in direct contact for extended

ULTIMATE BONY FUSION OF LOWER LIMB JOINTS FOLLOWING SEVERE TRAUMA

JOHN PATRICK O'BRIEN

The Duchess of Kent Children's Orthopaedic Hospital and Convalescent Home, Sandy Bay, Hong Kong, and Department of Orthopaedic Surgery, University of Hong Kong Hong Kong

Three patients presented with limb deformity some years after being run over and sustaining degloving injuries of their lower limbs. Spontaneous joint fusions were observed in each patient. The causes of these could be 1) Extensive intra-articular fracture, 2) Prolonged immobilisation due to the scar tethering the joint, or most likely 3) A chronic low grade infection following compound joint injury with degloving.

Key words: articular joints, epiphyseal injury, spontaneous fusion trauma

Accepted 29 III 77

It is well established that severe crush injuries to an epiphyseal plate will cause it to fuse prematurely and if significant growth potential remains, it will produce a shortened limb. This is the so-called type (v) injury of the epiphyseal plate described by Salter & Harris (1963). Spontaneous fusion of lower limb joints following injury is much less common. The purpose of this paper is to report three cases of this type and to comment on their possible aetiology.

CASE REPORTS

Case 1 A 24 year old male complained of a stiff knee and shortening of the right lower limb. When 8 years old his limb had been run over by a car, resulting in an extensive degloving injury of the entire limb and a fracture of the mid shaft of the femur. The details of the initial treatment were not available but it was essentially replacement of the degloved skin and

conservative management of the fractured femur.

On examination 16 years later, there were signs of extensive healed scars over the entire limb. There was bony ankylosis of the knee with 4 cm of limb shortening. Both the ankle and knee joints were fixed in 30° of flexion.

Radiographs confirmed bony fusion of all three compartments of the knee joint in addition to the ankle and subtalar joints (Figures 1, 2 and 3).

Case 2 A 16 year old male had his right leg run over by a car when he was a child aged 8 years. There was no history of a fracture but there had been extensive degloving of the medial aspect of the ankle and foot. Radiographs 9 years later demonstrated fusion of the ankle joint with the lower tibial growth plate intact (Figure 4).

Case 3 A 16 year old female presented with a valgus foot deformity. When aged 7 years her right lower limb had been run over by a bus resulting in a degloving injury.

Radiographs revealed premature fusion of the growth plates at both ends of the fibula with separation of the superior tibio fibular joint. There had been spontaneous fusion of the entire

case 1



Figure 1 Case 1 Antero-posterior radiograph of right knee in 21 year old male. Severe degloving injury of limb when aged 8 years. Note that bony fusion of the knee joint has occurred in the condylar notch still visible (n)



Figure 2 Case 1 Lateral radiograph of the same knee showing spontaneous bony fusion of the patellofemoral (arrow) and the tibiofemoral joints

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DISCUSSION

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periods of time, it was totally replaced with intra articular fibrosis and eventually bone ankylosis.

The scar tissue replacing skin and fatty tissue around the affected joints in this present series could have acted as a tether and a form of external bracing to the conjoined joints providing a degree of external prolonged immobilisation.

An additional factor could have been the reduced blood supply to the joint with consequent poor cartilage nutrition and its subsequent atrophy. All the affected joints reported here were largely covered by unstable thin skin graft or by tough, thick scar tissue, the result of healing by granulation and then fibrosis.

A likely precursor to joint fusion is the presence of chronic low grade infection destroying articular cartilage. All these injuries were the degloving type after being run over, and it must be assumed that there was a high incidence of compound injuries making joint infec-

tion a likely sequela. With this destruction of cartilage the naked bony epiphyses are placed in contact and inevitably bony fusion will occur.

This type of traffic injury to the lower limbs is common in children in Hong Kong where roads are narrow and both cars and children numerous. These late findings are less common in European communities where, with extremely severe lower limb trauma, amputation is more likely to be carried out as a primary method of treatment. In Hong Kong this is rarely the accepted treatment.

REFERENCES

- Enneking W F & Horowitz M (1972) The intra articular effects of immobilisation on the human knee. *J Bone Jt Surg* 54-A 973-982.
- Salter H B & Harris W R (1963) Injuries involving the epiphyseal plate. *J Bone Jt Surg* 45-A 587-622.

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Figure 3 Case 1 Lateral radiograph of foot and ankle of same patient. Note that fusion of the ankle and the subtalar joints have occurred with the foot in an equinus position. No radiological signs of premature epiphyseal plate fusion.



Figure 5 Case 3 Antero-posterior radiograph of leg of a 16-year-old female who had a severe degloving injury of the limb when aged 7 years. Fusion of the upper and lower fibular epiphyseal plates has occurred, also fusion of the ankle joint with the ankle in a valgus position.

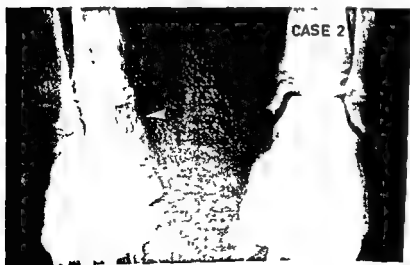


Figure 4 Case 2 Antero-posterior radiograph of both ankle joints showing bony fusion of the right ankle joint. Site of previous right ankle is level with lower fibular epiphyseal plate.

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REFERENCES

- Finckel W F & Horowitz M (1962) The intra articular effects of immobilisation on the human knee. *J Bone Jt Surg* 54-A 973-985.
- Salter H B & Harris W H (1963) Injuries involving the epiphyseal plate. *J Bone Jt Surg* 45-A 587-622.

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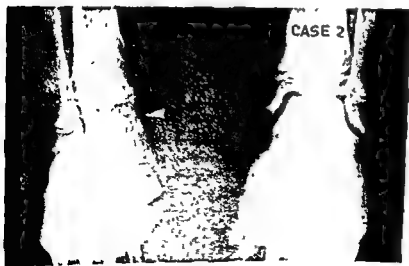


Figure 4 Case 2 Antero-posterior radiograph of both ankle joints showing bony fusion of the right ankle joint. Site of previous right ankle is level with lower fibular epiphyseal plate.

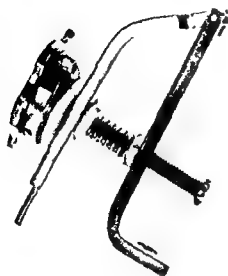
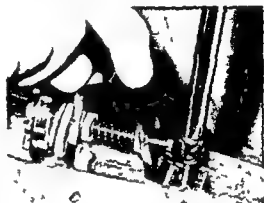


Figure 1 General view of the compression device designed for the technique described

centre (see Figure 2). The graft should be reversed and one screw located distally to the compression device until the graft surface is level with the existing bone. The graft is now secured to the distal fragment by both shear and compressive forces at the sawn surfaces. A 4 mm diameter hole is then drilled in the graft approximately 10-15 mm from its



from the medial aspect of the tibial shaft such that it is slightly tapered (by approximately 1.2 mm) and the section should also be tapered towards the bone

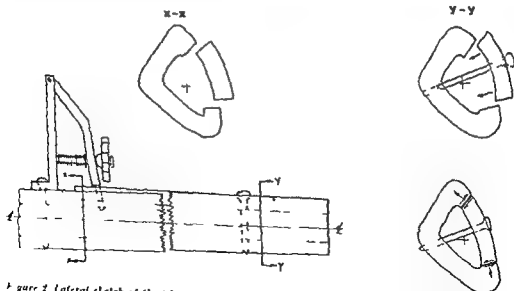


Figure 2 Lateral sketch of the tibia with the sliding bone graft in position before the application of compression at the fracture site. The cross sections show the position of the graft in the distal and proximal ends of the shaft. Photograph shows device in position just before compression is applied.

PRELIMINARY REPORT OF A COMPRESSION TECHNIQUE TO APPLY TENSION TO SLIDING BONE GRAFTS IN TIBIAL SHAFT FRACTURES

R J MINNS & P L FRANK

University of Durham, Durham and Hope Hospital, Salford Lancs UK

A new compression device is described that applies tension to sliding bone grafts on the medial aspect of the tibia in tibial shaft fractures. The mechanical aspects of the operation are outlined and the advantages and disadvantages of the system discussed. There have been no complications and rigidity has been obtained in two clinical cases. Mechanical tests in bending and torsion show that rigidity can be obtained without breaking the graft.

Key words: tibial shaft fractures, grafting, rigidity, reduction, fracture fixation

Accepted 23 Jan 77

Sliding bone grafts for the treatment of tibial shaft fractures have been used during immobilization (Holden 1973), however, it is well known that applying tension across the fracture site by compression plating decreases the time to full union due to the increased rigidity this system affords (Anderson 1965, Harris 1965, Muller et al 1970, Lettin 1965). Applying tension to sliding bone grafts was therefore considered, as this may very well add rigidity to a well-established treatment for delayed or non-union. The existing Muller compression device, however, is unsuitable for use with sliding bone grafts since the protruding lip on the movable leg stands clear of the surface and will not pass through the hole made in the cortex of the graft. A new device was designed which would allow tension to be applied to a sliding bone graft, resulting in compression at the fracture surfaces.

Description of device

The device consists of a fixed leg 8.0 cm in length and a movable leg which is pivoted by means of a small hinge at the top. Approximately a third of the way up the fixed leg a $\frac{1}{4}$ inch UNF screw passes through a slot in the movable leg and is screwed through the fixed leg at right-angles. A large movable knob is situated on the screw to allow the movable leg to rotate about the hinge, a weak spring causing the two legs to stay apart. The lip on the movable leg is positioned below the level of the bone surface so as to engage into a hole drilled in the sliding graft. Figure 1 is a view of the compression device.

Mechanical aspects of the operational techniques

To obtain a greater surface area of contacting bone the graft should be sawn

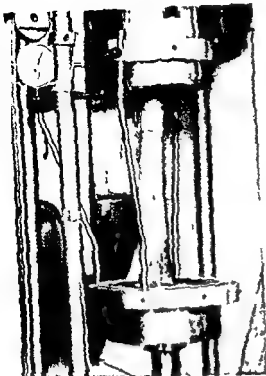


Figure 4 General view of the mechanical testing rig showing a tibia undergoing bending in the antero-posterior plane

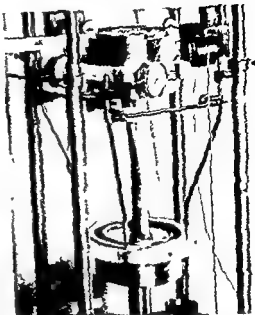


Figure 5 View of the mechanical testing rig showing a tibia undergoing a torsion test

Table 1 Results of bending tests on 17 tibiae used in conventional plating studies and three tibiae subjected to bending after experimentally applying a sliding bone graft to compress the two fractured surfaces. The fracture was artificially produced by a saw cut (Units are Newton metres/millimetre deflection)

	Intact		Plated	
	V/P	M/L	A/P	M/L
Mean of 17 tibiae	6.18	3.72	3.69	1.69
Sliding bone grafts	5.07	3.42	0.65	0.40

Table 2 Results of torsion tests on the 17 control plated tibiae and the three sliding bone grafted tibiae (Units are Newton metres/degree angulation)

	Intact	Plated
Mean of 17 tibiae	4.40	1.96
Sliding bone grafts	2.72	1.71

rigidity. The technique of specimen preparation and testing procedures is described in Minns et al (1975). Bending was applied in the antero-posterior plane using the equipment shown in Figure 4, the deflections being recorded by a dial gauge situated at the distal end of the tibia. Torsion was applied about the shaft axis as shown in Figure 5, two dial gauges recording angulation about the axis. Three further tibiae were tested in which sawn artificially produced mid-shaft fractures were reduced by sliding bone grafting, the sliding graft being seen from the antero-medial aspect.

The bending and torsional stiffnesses of the tensioned sliding bone graft are low (see Tables 1 and 2) compared to metal or fix plates. It may be true that a bending moment on the shaft introduced by tension applied to the graft using the

device, placed within a cortex, is smaller than the one produced by a plate, placed on the subcutaneous side, but the bone is

end to locate the lip on the movable leg of the compression device. The compression device is then attached by a 4 mm bone screw in the fixed leg and the graft should be raised above the bone surface so that on applying compression the two fracture surfaces approach each other with the opposite cortex contacting first so that equal compression will be applied when finally tightened (see Figure 2). Figure 3 shows the situation just prior to removal of the compression device. The two screws in the proximal fragment are angled towards the fracture so that when the compression device is removed, the tension in the graft is taken by these screws and will also bring the graft towards the centre of the bone (see section A-A, Figure 3) as there is now a slight gap due to the reverse taper

quickly without the use of additional equipment, as with other compression devices normally used for compression plating, the long stem allowing good purchase within the hole in the graft. The length of the stem also ensured that tension was applied parallel to the shaft of the bone, consequently causing even compression around the fracture cortex and not compression at an angle that would tend to open the graft and possibly break it.

Mechanical studies

Seventeen left tibiae were tested in bending and torsion to evaluate the effect of antero medial plating on mechanical

Clinical experience

One of us (P I F) has had the opportunity to insert two sliding bone grafts and they have withstood the tension without difficulty and compression was applied at the same time to the fracture site. The grafts have become incorporated and none of the screws used for fixation of the graft have had to be removed. The compression device described allowed the compression to be performed

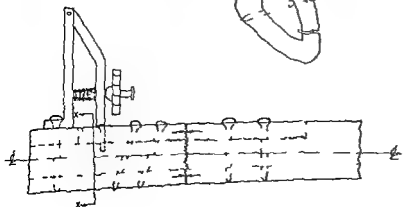


Figure 3 Situation of the internal components after the application of compression just prior to removal of the device

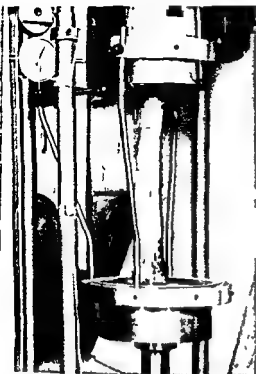


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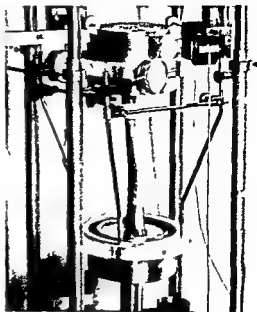


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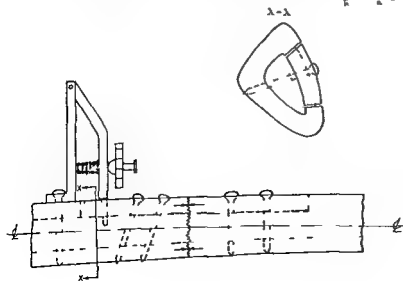


Figure 3 Position of the tibial components after the application of compression just prior to removal of the device

STEN FRIBERG IN MEMORIAM

Sten Friberg, one of the pioneers and outstanding leaders in Scandinavian and international orthopaedics died in Spain on May 3rd 1977. A brief summary of his creative professional life will be appreciated by his contemporaries and friends and an inspiration to younger readers.

Sten Friberg was born and raised in Stockholm. After a comprehensive surgical and orthopaedic training he was appointed head of the orthopaedic service in Lund in 1941 and in 1943 he succeeded Henning Waldenström to the chair of orthopaedics at the Karolinska Institute in Stockholm.

The scientific basis for orthopaedics in Sweden was laid down by Waldenström and Sten Friberg, built further on this foundation. In his department at Norrbacka in Stockholm he developed a comprehensive service for the disabled and promoted clinical and experimental research primarily concerned with hip and spine problems, later with arthroplasties, tumours and arterial reconstructions as well.

He realized at an early stage that the traditional segregation of orthopaedics and traumatology had to be eliminated if further progress was to be made. Accordingly he worked for recognition of a concept of orthopaedics expanded to include care of and research into disorders and injuries of the total musculoskeletal system. This field was to be treated for by orthopaedic surgical wards in the teaching hospitals as well as in the county hospitals. His political ability



his firm though tactful approach and dedicated endeavours have been of great value in establishing today a general acceptance of orthopaedic surgery as an integral part of general hospital care in Sweden. When he was appointed professor in 1943 his chair of orthopaedics was the only one in Sweden. Today there are nine professors of orthopaedic surgery in Sweden and orthopaedic departments are to be found in all counties.

His achievements in this respect also had a great impact on the other Scandinavian countries.

many times less strong under bending than the currently available implant materials. The torsional stiffness would be expected to be very much lower than that obtained in plated tibiae because the torsional strength of the bone as a circular tube is many times reduced by the fact that the circumference of the bone is slit open (Brooks et al 1970). However, some torsional rigidity can be obtained very close to plated tibiae even when applying a tensile stress to the bone below its fracture strength, possibly because the graft becomes continuous with the cortex at any section. Obviously the technique is limited to fractures that have a sufficient length of graft available to accommodate four screws; probably it must be longer than 15 centimetres.

REFERENCES

- Anderson I D (1965) Compression plate fixation and the effect of different types of internal fixation on fracture healing *J Bone Jt Surg* 47 A, 191-208
- Brooks D H, Burstein A H & Frankel V H (1970) The biomechanics of torsional fractures. The stress concentration effect of a drill hole *J Bone Jt Surg* 52 A, 507-514
- Harris N H (1965) Clinical experience with the Muller compression device *Proc roy Soc Med* 58, 879-882
- Holden C I A (1973) Bone grafts in the treatment of delayed union of tibial shaft fractures *Injury* 4, 179
- Ilett A W I (1965) The effect of axial compression on the healing of experimental fractures of the rabbit tibia *Proc roy Soc Med* 58, 882-886
- Minns R J, Campbell J & Bremble G R (1975) The bending stiffness of the human tibia (*calcif Tiss Res* 17, 165-168)
- Muller M E, Allgower M & Willenegger H (1970) Manual of internal fixation. Springer Verlag, Berlin

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CELL PROLIFERATION IN BONE MARROW AND THYMUS FOLLOWING SOFT TISSUE DAMAGE

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Earlier experiments by the author have shown that an increase in mitosis in bone marrow and thymus occurs after fractures and bone marrow aspiration. In this paper it is shown that soft tissue damage causes a statistically certain increase in mitosis both in bone marrow and thymus after 1 day. A possible explanation for this is liberation of a mitogenic kinin.

Key words: mitoses, bone marrow, thymus, wound, cell proliferation.

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Mitotic stimulation in rat bone marrow and thymus has been reported following standardized bleedings (Perris et al 1971), administration of parathyroid hormone (Perris et al 1967, Perris & Morgan 1976), and injection of calcium (Perris et al 1967) and kinins (Rixon et al 1971).

In fractures autoradiographic studies of the proliferative response of osteogenic cells in mice have shown a mitogenic effect of the osteoblasts in the fractured bone and to a certain degree even in the opposite bone (Tonna & Cronkite 1961, Hildebrandt et al 1974). In an earlier report by the author of this paper it was shown that after femoral and tibial fracture in growing rats the mitotic activity increases in the first 2 or 3 days in the opposite femoral bone marrow and in the thymus (Hulth & Johnell 1976). In order to look at the reaction from the

bone marrow locally, we aspirated bone marrow from right femurs and found an increase of mitotic activity in the bone marrow of the opposite femur and in the thymus though to a slightly smaller extent than in the fracture group (Hulth & Johnell 1977). In the present study, the mitotic activity in bone marrow is investigated after damage to soft tissue.

MATERIAL AND METHODS

Thirty-one inbred Sprague Dawley rats weighing 100 and 120 g were used. They were divided into a control group and a soft tissue damage group. In the latter group under anaesthesia a dorsal incision approximately 3 cm in length was made over the lumbar spinal processes cutting through the skin and the muscles, the skin being thereafter sutured. The rats were kept in a cage and supplied with food *ad libitum*. In the experimental group the animals were killed after 1, 2, 4 and 7 days.

The rats were given two injections of colchicine each (0.2 mg/100 g body wt) intraperitoneally 6 and 3 hours before they were killed by an overdose of ether. The reason for the two injections of colchicine was to prevent the escape of

Financial support was obtained from Herman Jarnhamns Stiftelse.

Many of those who now have the responsibility for orthopaedic surgical care, teaching and research in Scandinavia continue his work and try to build further on what Sten Friberg has created, they will always remember him with gratitude.

Sten Friberg's talent for administration and his personal capacity were recognized by national and international organizations. He was elected dean of the medical school and chairman of the Nobel committee. During the years 1953-1969 he had to reduce his clinical work as professor and head of the department as he at the same time held the position of dean (rektor) of the Karolinska Institute. For the Karolinska Institute this was a period of very expansive activity. Sten Friberg, however, maintained his deep interest in his patients and in the development of research projects carried out by his associates and pupils. Through his profound interest in teaching, his wish to guide and his ability to listen he also gained the appreciation and gratitude of the students.

In 1951 he was congress president for SICOT and arranged a most successful congress in Stockholm, which a number of orthopaedic surgeons from all over the world will long remember. In 1966 he was elected president of SICOT and during the triennium he invested great efforts in strengthening the society.

Acta Orthopaedica Scandinavica will remember Sten Friberg with great gratitude. Over a period of more than 20 years Sten Friberg was editor of our journal. The position of *Acta* as an important international journal is essentially due to his vision and endeavours.

Sten Friberg received numerous honours at home and abroad and he enjoyed the friendship of colleagues in all parts of the world.

He was always faithfully supported by his dear wife, Gudrun, who also acted as a charming hostess to their mutual guests. To Mrs Friberg and to the Friberg family we extend our deepest sympathy.

Tor Hjerten

Knud Jansen

how bone and soft tissue trauma cause increased mitotic bone marrow activity

It has previously been shown that injection of bradykinin also causes an increased mitotic activity in bone marrow and thymus thus supporting the theory of mitogenic kinins. In this experiment, it might be possible that mitogenic kinins are liberated from the trauma site, even though the parathyroid hormone might also be involved.

It is impossible to say, at the present stage of the research what is the purpose if any, of the bone marrow cell proliferation after various types of trauma. After haemorrhages, of course the bone marrow stem has to substitute the lost blood cells. It is perhaps possible that the cellular response of the bone marrow has some important purpose in producing cells for migration into the fracture site or the soft tissue wound.

REFERENCES

Hult H & Johnell O (1976) Cell proliferation in the bone marrow and thymus following fractures in rats (*Acta Orthop* 120: 260-263).

- Hult H & Johnell O (1977) Cell proliferation in bone marrow and thymus following partial bone marrow aspiration. *Experientia (Basel)*. In press.
- Hunt N H & Perris A D (1973) Calcium and the control of circadian mitotic activity in rat bone marrow and thymus. *J Endocr* 62: 451-462.
- Hjäldebrand V, Damholt W & Nordentoft E L (1974) Investigation of cellular response to fracture assessed by autoradiography of the periosteum. *Acta orthop scand* 45: 175-181.
- Perris A D, Whitfield J F & Rixon N H (1967) Stimulation of mitosis in bone marrow and thymus of normal and irradiated rats by divalent cations and parathyroid extract. *Radiat Res* 33: 550-563.
- Perris A D, MacManus J P, Whitfield J F & Wells L A (1971) Parathyroid glands and mitotic stimulation in rat bone marrow after hemorrhage. *Amer J Physiol* 220: 773-777.
- Perris A D & Morgan J I (1976) The interaction of divalent cations, hormones and cyclic nucleotides in the control of mitosis. (*Calcif Tiss Res* 21 (Suppl.) 15-20).
- Rixon N H, Whitfield J F & Bayliss J (1971) The stimulation of mitotic activity in the thymus and bone marrow of rats by halalkalins. *Horm Metab Res* 3: 279-284.
- Tonna E A & Cronkite E P (1961) Cellular response to fracture studied with tritiated thymidine. *J Bone Jt Surg* 43 A: 352-362.

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cells in metaphase from the initial block. All animals were given the injections at the same time (the first injection between 8 and 8.30 a.m.) in order to avoid the circadian fluctuations in mitotic activity of bone marrow and thymus (Hunt & Perris 1973).

Groups of normal rats and rats after soft tissue damage were used for haematocrit determinations. The thymus gland and the left femur were removed. The thymocyte and bone marrow cell suspensions were prepared in a balanced glucose salts medium (5.5 mM glucose, 5.0 mM KCl, 0.63 mM CaCl_2 , 1.0 mM MgSO_4 , 5.0 mM NaHPO_4 , 120 mM NaCl, 5.0 mM Tris buffer (pH 7.2)). The thymocyte suspension was prepared by mincing the gland in the medium with scissors, the resulting suspension being filtered through gauze. To prepare the suspensions of bone marrow cells, the ends of the femurs were removed and the core of marrow was "washed out" with 1.5 ml of the medium and then dispersed by passing the tissue several times through a syringe with an 18-gauge needle. Then both thymus and bone marrow suspensions were gently centrifuged.

Samples of the cell suspensions were placed on slides immediately fixed in alcohol, and stained in haematoxylin-eosin. The slides were scored for the percentage of the total cell population in metaphase. Each preparation had two slides and at least 500 cells were counted on each (a total of at least 1000 cells were counted). During the counting procedure the slides were labelled in code.

RESULTS

In the soft tissue damage group, the mitotic activity was increased in the bone marrow cell suspension from the left femur 1 day after the trauma ($0.1 > P > 0.001$), returning towards the normal value (Figure 2). The haematocrit of the thymus cells, arrested in metaphase, increased 1 day after the damage ($P < 0.001$) and then returned to the normal value (Figure 2). The haematocrit did not differ from the control animals in the experimental group.

DISCUSSION

Various types of trauma seem to increase bone marrow and thymic cell mitotic

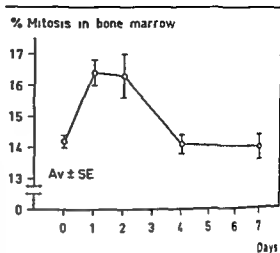


Figure 1 Percentage of total cells in metaphase in bone marrow from the left femur after colchicine injection

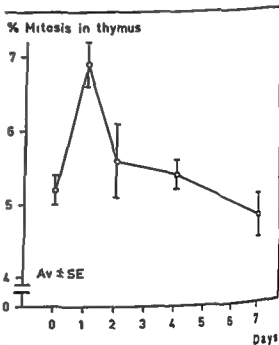


Figure 2 Percentage of total cells in metaphase in thymus after colchicine injection

activity. This is valid not only for standardized bleedings (Perris et al 1971) and fractures (Hulth & Johnell 1976) but also for slight trauma such as bone marrow aspiration (Hulth & Johnell 1977). In this paper it is shown that a soft tissue incision gives the same result. The mitotic activity after bleeding is governed by the parathyroid gland but it is not certain

originating from surface cracks during testing the machining was done lengthwise on an automatic lathe

The samples were then tested in bending to rupture in a Zwick Z 1-3D test rig. The samples were loaded centrally with a deformation speed of 6 mm per minute. The modulus of elasticity (Young's modulus), hereafter called E modulus was determined from two readings on the ascending part of the curve obtained. The E modulus was calculated from the readings using a nomogram constructed for the purpose according to the formula

$$F = \frac{L^3}{4 \times bh^3} \times \frac{\Delta F}{\Delta l} \text{ kp/cm}^2$$

(Weast 1968)

l = distance between supports

b = width of sample

h = height of sample

ΔF = increase of load

Δl = deformation

The samples were then further loaded until rupture and the flexural stress was read directly from the graphs obtained from the test rig. The flexural strength was calculated from the formula

$$S_{\max} = \frac{3}{2} \times \frac{F_{\max} \times L}{b \times h^2}$$

F_{\max} = stress at rupture

The experiments were made at room temperature (22°C). However E modulus and flexural strength were also determined at 38°C for all three brands of cement. CMW and Simplex P were tested without any additions but Palacos was only available as Palacos R & is with Zirconium dioxide as radio-opaque substance already added. CMW was tested with the addition of 2.5 and 5 g of barium sulphate as indicated by the manufacturer while Simplex was tested both pure and in the form of Surgical Simplex II Radiopaque which also contains BaSO_4 . Macroscopically the BaSO_4 was difficult to distribute evenly in the CMW. There was a tendency for small clumps of the substance to stick together and they were visible on the surface of the test samples. All brands of cement were tested with gentamicin added as this antibiotic

was added to each brand was prepared and tested after the gentamicin had been washed out at body temperature in human plasma as indicated by Holm & Vellgaard

(1976). Also the three types of cement were tested for possible changes of values due to afterpolymerization. Samples were tested 8 h after mixing and others at 24 h and 1 week after initial polymerization. All other samples were stored for at least 3 weeks at room temperature to eliminate any effect of afterpolymerization on the results. A total of 376 tests were made.

RESULTS

E-modulus

The measured values were treated statistically by parametric variance analysis and the Student-Newman Keul procedure. These analyses showed for all types of cement that the variation between the eight determinations of E-modulus obtained from each portion of cement was significantly smaller than the variation between the portions of cement prepared in different ways ($P < 0.01$). The standard deviations of the eight measurements per package were for CMW 1.54, for Simplex P 1.16, and for Palacos R 1.15. Standard deviations between different portions of cement were two to four times larger.

The values of the E-moduli in each type of cement fell into 3-5 groups that were significantly different whereas the values within each group did not differ significantly from each other. In the case of CMW the groups were not sharply delineated statistically speaking, but overlapped somewhat. This means that for some factors significant differences cannot be demonstrated with certainty, however indicative tendencies were found. Where percentages are given in the following they are only to be taken as approximations. Mean values are given in Table I.

For CMW the E-modulus calculated from the results for the portions of cement without additions was found to be 26,000 kp/cm^2 , Simplex P showed a value of 24,600 kp/cm^2 , and Palacos R (Zirconium dioxide added) was found to have an E-modulus of 23,900 kp/cm^2 .

THE MODULUS OF ELASTICITY AND FLEXURAL STRENGTH OF SOME ACRYLIC BONE CEMENTS

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The modulus of elasticity and flexural strength were measured for three bone cements, CMW Bone Cement, Surgical Simplex and Palacos R with various additions and prepared as in actual use. A distinct afterpolymerization was demonstrated in all three brands. The addition of blood lowered the E modulus whereas radio opaque media seemed to render them somewhat stiffer. The rupture values demonstrated the inhomogeneity of the final product in all three brands. The possible clinical significance of the findings is discussed.

Key words: bone cement, E modulus, flexural strength

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The use of polymethylmethacrylate as a means of fixation of total joint replacements has become an established procedure. The present study was intended as a contribution to the understanding of the nature of some of the bone cements available. A comparative study of variations in the modulus of elasticity and the flexural strength as a result of the addition of various substances was carried out as a preliminary analysis.

MATERIAL AND METHODS

In order to get an impression of the physical characteristics of the substance as used in surgery, it was decided to use a preparation technique resembling as closely as possible that of actual use, i.e. manual mixing, stirring and handling. Three brands of cement were tested: CMW Bone Cement®, Surgical Simplex® and Palacos R®. All test samples were prepared from packages from the same production batch as indicated by the numbers on the packages. The cement was in each case mixed according to the instructions of the manufacturer described

in the directions accompanying the packages. In each case a whole package of bone cement powder (40 g) and a vial of monomer of about 20 g were mixed. All additions of dry substance, i.e. BaSO₄ or gentamicin, were made to the powder and mixed well with this before adding the liquid monomer.

As it is not possible to measure the amount of blood added to cement during actual use in surgery, it was chosen to investigate the effect of the addition of two quantities, 1 ml and 3 ml of heparinized whole blood to the cement. The amount of blood was measured with a standard injection syringe. The blood was added to the cement as soon as the powder monomer mixture had become liquid and was mixed into the cement by stirring. It was possible to mix the blood into the cement quite evenly without stirring more vigorously than usual.

After mixing the cement was pressed manually into an open mould. The mould was closed and held together with clamps during polymerization in order to obtain complete filling of the mould. Each package yielded eight test samples measuring 4 × 10 × 110 mm. After polymerization the test bodies were removed from the mould and excess cement was machined off so as to obtain the exact thickness of 4 mm. In order to minimize the risk of early rupture

The E-modulus showed a statistically significant increase for all three brands during the first week after polymerization as indicated by the values obtained at 8 hours, 24 hours, and 1 week after initial polymerization. The increase amounted to 5 per cent for Simplex, 7 per cent for CMW, and 8 per cent for Palacos.

Table 1 Modulus of elasticity, mean values of eight determinations per package of cement ($n \times 10^3$ kp/cm²)

Addition	CMW	Simplex	Palacos R
None, 8 h	24.4	23.8	22.2
None, 24 h	25.9	24.2	23.8
None, 7 days	26.5	25.3	24.4
None, 3 weeks	26.7	24.1	24.4
do	25.3	24.4	23.1
BrSO ₄ , 2.5 g	28.0	25.1	
do	27.0	26.7	
do	27.4		
do	29.8		
BrSO ₄ , 5.0 g	26.3		
do	25.6		
Gentamicin 10 g	26.9		
do	25.5		
Gentamicin, 0.5 g		22.5	23.9
do			23.9
Blood, 1 ml	21.8	25.6	25.3
do	23.9	26.7	24.3
Blood, 3 ml	20.1	24.1	23.3
do	20.8		23.2
Gentamicin eluted	23.0	23.6	23.3
None 38° C	26.9	24.7	22.5

Adding 2.5 g BrSO₄ to one portion of CMW increased the E-modulus in all tests though only one test showed values that were with certainty statistically increased (about 10 per cent). The radio opaque Simplex also showed a tendency towards greater stiffness than the pure preparation, but only one determination was significantly increased (8 per cent).

Adding blood to CMW decreased the E-modulus, 1 ml of blood caused a decrease of about 12 per cent. This change was further augmented by adding 3 ml per portion, a decrease of 21 per cent

giving the lowest value recorded in the series. In the case of Simplex, the results were somewhat different, showing slight increase in the E-modulus after addition of 1 ml of blood, but the values are only statistically significant in one case. Adding 3 ml of blood again gave lower values. In the case of Palacos R the results of adding 1 and 3 ml of blood fell into separate statistical groups, the smaller amount of blood showing no change of E-modulus whereas the larger amount decreased the E-modulus by about 3 per cent which is statistically significant.

Adding a soluble substance such as gentamicin sulphate to CMW in an amount of 1 g per portion of cement tended to decrease the E-modulus a little though the values are not statistically significant, but when the antibiotic had been washed out the E-modulus decreased about 11 per cent, this figure being statistically significant. Surgical Simplex showed a similar pattern with a decrease in E-modulus of about 8 per cent in spite of the fact that only 0.5 g of gentamicin was added in this case. Refobacin-Palacos R showed values 5 to 6 per cent lower than Palacos R. The elution of the gentamicin from Simplex and Refobacin-Palacos R did not result in any further significant decrease of E-modulus.

The increase of ambient temperature to 38° C gave slightly lower values, but only in the case of Palacos R was the difference statistically significant, about 6 per cent.

Flexural strength

The values of flexural strength, i.e., the maximum stress at rupture of the test sample (expressed in kp/cm²) were widely scattered. Standard deviations within the groups of eight samples originating from the same portion of cement varied from 4.1 per cent to 10.6 per cent.

tact area. This greatly increases the stability of the prosthesis (Charnley 1963a).

During activity when a prosthesis is put under stress an elastic deformation of all components involved takes place at each step. The magnitude of this deformation is dependent on the E modulus of the substance involved: the smaller the E modulus the greater the deformation. It is therefore obvious that when two substances of different E moduli in contact with each other are put under stress in a direction parallel to their common surface as is the case with cement in contact with bone on one side and the femoral prosthesis on the other movement will take place between them because one substance will show greater deformation than the other. The phenomenon is called *fretting* and has been described by Charnley (1963) in relation to the anchoring of the femoral stem of the total hip replacement. Charnley considers the cement to be an integral part of the prosthesis. This cannot be entirely true as the cement and the metal of the prosthesis have greatly different E moduli. As blood and soluble and insoluble additions to the cement may be unevenly distributed throughout the cement the substance will show varying elastic deformations throughout its volume thereby putting greater stress on stiffer areas. The results of the breaking tests where the samples in some cases shattered show that uneven polymerization may give rise to intrinsic stresses in the cement and such pre-stressed areas further complicate the pattern of stress and deformation throughout the cement. The inclusion of air bubbles and vacuoles from dissolved substances will form critical points of weakness from which cracks in the cement may originate. It is thus not uncommon to find fractures of the cement in cases of prosthetic loosening in the absence of infection. Charnley reports such a case in his monograph of 1970. An increased risk of mechanical

failure might for the same reasons be encountered in the cement protrusions that interlock with the bony trabeculae causing microfractures of either bone or cement and hence loosening.

The most important conclusion must however be that the mixing and the method of application of the cement is the most important factor as regards the strength of the final product. In spite of the fact that careful preparation of all cement was carried out according to the instructions of the manufacturer the end result was extremely inhomogeneous and demonstrated how different even portions of the same manufacturing batch may turn out in actual use. The very large standard deviations of the breaking tests with considerable variation even within the same portion of cement underline the problems. It is therefore concluded that careful stirring and mixing of ingredients is important if ready mixed preparations are not used. It must be considered of importance to have as dry an operating field as can be obtained so as to avoid the decrease in E modulus resulting from the addition of blood. The use of a cement syringe as advocated by Slooff (1973) would seem a reasonable procedure in order to obtain as homogeneous a cement as possible.

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REFERENCES

- Buelh, H. W. & Engelbrecht, H. (1970) *Über die Deputierung einiger Antibiotika bei Verwundung mit dem Kunststoff Palacos R*. *ratg* 41, 511-515.

der contains an initiator, usually benzoyl peroxide and BaSO_4 or ZrO as radio-opacifier and may contain copolymers such as styrene or butylmethacrylate to improve handling (Laulenschlager et al 1974). The monomer contains a catalyst, mostly tertiary amines, and a stabilizer such as hydroquinone. The cement is mixed manually with a spoon or spatula in a bowl, and polymerization depends on an even distribution in the mixture of catalyst and oxidizer. A varying amount of air is added during the process yielding a very heterogeneous substance which is further kneaded, folded and mixed with blood during application. It is not surprising that one often notices that the cement still may be soft in places while other parts have already become hard as an indication of uneven polymerization. This study was aimed at illustrating the variations in physical properties as encountered in surgery and this is the reason why the cement was handled as it is in actual use.

The first question raised by this investigation is the difference between the E-modulus of Palacos R found in the present results and that indicated by the manufacturer in the brochure included in the cement package (15,500 kp/cm²). The values found in the present investigation correspond well with those of other brands of polymethylmethacrylate investigated and are of the same order of magnitude as values commonly indicated for other commercially available acrylics. However, the values indicated by Buchholz & Engelbrecht (1970) correspond well with the values of the manufacturer. Personal correspondence with the manufacturer (Hulzer & Co.) has given no answer to the question.

An increase in the E modulus occurred during the first week. This must be interpreted as the effect of afterpolymerization and is caused by an increase in length of the molecular chains and possibly also the polymerization of about

3 per cent of the monomer not polymerized immediately (Haas et al 1975, Feith 1975, Charnley 1970). With CMW the addition of radio-opacifier is done by stirring the BaSO_4 powder into the cement powder. It seemed difficult to distribute the BaSO_4 evenly in this way and there was a tendency for small clumps of the substance to stick together. These were visible as little white specks on the surface of the samples. This was not the case with the two other brands where the cement and the radio-opacifier are mixed by the manufacturer. The reduction of E-modulus in CMW mixed with 5 g of BaSO_4 cannot be explained with certainty, but it is possible that with increasing amounts of BaSO_4 this substance begins to act as a filler and causes a decrease in the amount of acrylic present in the cross section of the test sample.

It is a common experience that cement hardens more quickly when mixed with blood, but the results show a smaller value for the E-modulus which must indicate a lesser degree of polymerization. This could be due to interaction of blood enzymes (catalase?) with the peroxides of the cement, breaking these down so fast that the necessary free radicals to complete polymerization are no longer available. The decrease in E modulus after the washing out of gentamicin of the cement is in accordance with Grunert & Ritter (1974), who found a change in E-modulus of about 8 per cent, whereas Buchholz & Engelbrecht (1970) found no change in their investigation. However, their values are as low as 16,500 kp/cm². As regards temperature sensitivity, the slight decrease of the E-modulus at 35°C is to be expected with a thermoplastic substance like polymethylmethacrylate.

The importance of using acrylic cement as a means of fixation in total joint replacement lies in the function of the cement as a filler between bone and prosthesis thereby distributing load and stresses more evenly over the entire con-

CHANGES IN BONE FORMATION DURING IMMOBILIZATION AND DEVELOPMENT OF EXPERIMENTAL OSTEOARTHRITIS

A Study using Oxytetracycline in Rabbits

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Helsinki, Finland

The effect of immobilization on bone formation in the knee and hip was studied by means of oxytetracycline. One leg of 11 growing and 13 adult rabbits was immobilized so that the knee was held in extension but the hip was free. In the knee degenerative changes developed consistently with a severity proportional to the length of the immobilization time. In most of the rabbits given oxytetracycline 1-13 days before they were killed considerably more oxytetracycline was incorporated in the bone in the immobilized knee region and slightly more in the hip region of the same leg than in the corresponding areas of the other leg. This indicates an increased turnover of bone tissue in the immobilized leg compared with the non-immobilized leg.

Key words: bone formation, experimental immobilization, osteoarthritis, tetracycline.

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Degenerative joint changes have been produced experimentally in animals by various methods (for instance, prolonged compression (Saltér & Field 1960, Trias 1961), induced instability (Tehlgren & Lindberg 1972) or immobilization of the joint in flexion or extension (Larsson et al 1960, Hall 1963 a, b). Immobilization of the knee in extension in young rabbits consistently causes deformities of the hip (Michélsen & Langenskiöld 1972 a, b, Michélsen & Langenskiöld 1973). In adult rabbits immobilization of the knee in extension for 6 weeks or more results in every case in degenerative changes in the knee and in some cases also in the hip (Langenskiöld et al 1975, Videman

et al 1975, Michélsen et al 1977, Videman et al 1977 a, b).

When oxytetracycline is administered to a rabbit, a part of the antibiotic becomes bound to the bone tissue. Deposition of oxytetracycline in bone is associated with the ossification process (Milech et al 1957). 'Adventitious' tetracycline disappears from the bone 2 days after the administration of the antibiotic and the residual antibiotic in newly-formed bone disappears only through resorption of bone (Frost et al 1960). As tetracyclines fluoresce in ultraviolet light (Siltzman 1950), they can be used as bone labels. The tetracycline technique is a valuable supplementary aid in the

- Charnley, J (1965) A biomechanical analysis of the use of cement to anchor the femoral head prosthesis *J Bone Jt Surg* 47 B 334-363
- Charnley, J (1970) *Acrylic cement in orthopaedic surgery* F & S Livingstone, Edinburgh and London
- Charnley, J & Kettlewell J (1965) The elimination of slip between prosthesis and femur *J Bone Jt Surg* 47-B, 56-60
- Felth, H (1975) Side effects of acrylic cement implanted into bone *Acta orthop scand* Suppl 161
- Grünert, A & Ritter, G (1974) Veränderungen physikalischer Eigenschaften der sogenannten Knochenzemente nach Beimischung von Fremdstoffen *Arch orthop Unfall Chir* 78 336-342
- Haas, S S, Brauer, G W & Dickson G (1975) A characterization of polymethylmethacrylate bone cement *J Bone Jt Surg* 57 A 380-391
- Holm N J & Vejlsøgaard, R (1976) The *in vitro* elution of gentamicin sulphate from methyl methacrylate bone cement *Acta orthop scand* 47 144-148
- Iautenschlager, I P, Moore H K & Schoenfeld C M (1974) Physical characteristics of setting of acrylic bone cements *J biomedical mater res symp* 1 185-196
- Slooff, T J J H (1971) Über den Gebrauch von Akrylzement in der orthopädisch chirurgischen Praxis *J Orthop* 109 511-521
- Weast, R C (1968) *Handbook of chemistry and physics* 49th ed The Chemical Rubber Co (Cleveland Ohio)

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Degenerative joint changes have been produced experimentally in animals by various methods: for instance, prolonged compression (Saltér & Field 1960, Trias 1961), induced instability (Teitlag & Lindberg 1972), or immobilization of the joint in flexion or extension (Evans et al 1960, Hall 1963 a, b). Immobilization of the knee in extension in young rabbits consistently causes deformities of the hip (Michelsson & Langenskiöld 1972 a, b, Michelsson & Langenskiöld 1974). In adult rabbits immobilization of the knee in extension for 6 weeks or more results in every case in degenerative changes in the knee and in some cases also in the hip (Langenskiöld et al 1975, Videman

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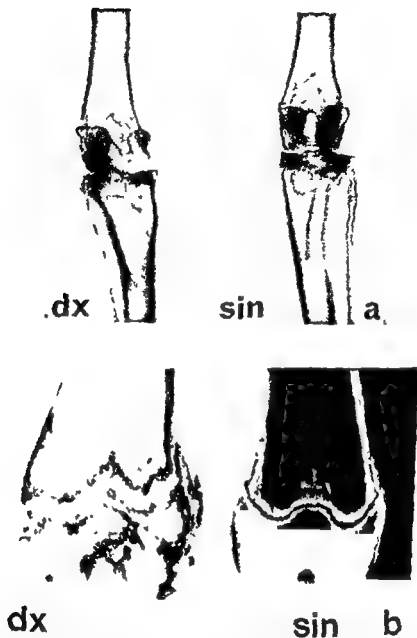


Figure 1 a, b A 3-month old rabbit (291) was immobilized with the right knee in extension for 5 weeks. Oxytetracycline was given before it was killed at the age of 6 months. Deformation of the right knee had developed. a) Radiograph taken of specimens. b) In the specimen of the distal end of the right femur a deformed thickened epiphyseal plate with oxytetracycline labelled bone on both the metaphyseal and epiphyseal sides is visible.

study of the bone formation occurring during immobilization.

In this study oxytetracycline was used to investigate new-bone formation in the knee and hip regions in rabbits in connection with immobilization of the knee and the development of osteoarthritis.

MATERIAL AND METHODS

Eleven growing rabbits 2-5 months old and 13 adult rabbits aged 9-13 months made up the experimental series. The right hind limb of the rabbits was immobilized with a plastic splint and Tensoplast® so that the knee remained in extension but the hip was free and movable. A corresponding technique for immobilization has previously been described in detail (Michésson

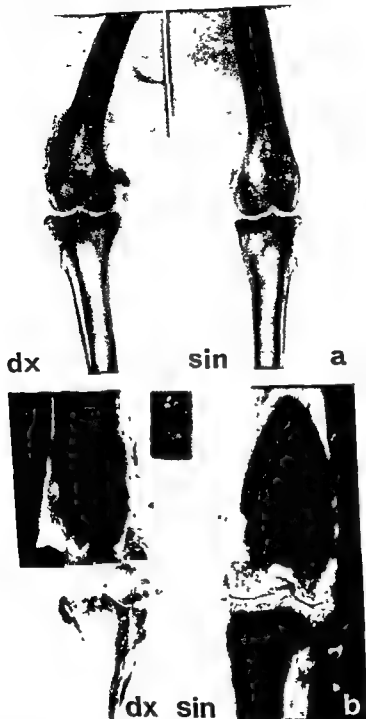


Figure 2 a b An adult rabbit (401) was immobilized with the right knee in extension for 7 weeks before it was given oxytetracycline and killed a; Marked degenerative changes of the right knee had developed and are visible on the radiograph b; In the specimen from the right knee the amount of oxytetracycline labelled bone was considerably greater than in the left knee (b)

Table 1 Content of oxytetracycline in knee and hip of the immobilized (right) leg compared with the left non immobilized knee and hip in 20 rabbits. The oxytetracycline was given some days before the animals were killed

Rabbit no	Age at immobilization in months	Duration of immobilization in weeks	Interval between immobilization and sacrifice in weeks	Oxytetracycline content in right knee	in right hip
Growing rabbits					
295	3	5	8	++	+
411	3	6	1	++	+
412	3	6	1	+	++
220	4	6	28	+	+
223	4	6	30	++	+++
398	5	6½	0	+	+
387	5	7	0	+++	+
389	5	7	0	++	+
388	5	8½	¼	++	+
192	5	8½	2	++	++
225	2	13	1	++	+
Adult rabbits					
395	> 12	2	1	+	+
II	12	4	52	+	+
III	9	5	78	—	—
401	> 12	7	0	+++	+
10	> 12	8½	52	+	—
375	13	13	34½	+	—
230	33	13	26	++	—
89	11	17½	1	—	—
303	16	17½	2	++	+

— not more oxytetracycline in the right (immobilized) joint than in the left
 + slightly more oxytetracycline in the right (immobilized) joint than in the left
 ++ moderately more oxytetracycline in the right (immobilized) joint than in the left
 +++ markedly more oxytetracycline in the right (immobilized) joint than in the left

Langenskjöld 1972b; Michelsson & Langenskjöld 1974).

The splint was removed after 2 17½ weeks and the animals were allowed to move freely.

The animals were killed 0-78 weeks after the immobilization period having been given 50 mg oxytetracycline per kg of body weight intramuscularly on three consecutive days. Nine adult and all the 11 growing rabbits were given the oxytetracycline injections 1-13 days before they were killed (Table 1). Four other adult rabbits were given oxytetracycline at the beginning of immobilization and were killed 49-90 days thereafter.

The hips and knees of the animals were dissected split in the frontal plane and examined in UV light. The knees and hips of the immobilized and non immobilized legs were com-

pared principally with regard to their oxytetracycline content.

RESULTS

In 18 of the 20 rabbits that received the oxytetracycline just before they were killed, the oxytetracycline content was higher in the bone tissue of the knee and in 15 of them also in the hip of the immobilized (right) leg than in the corresponding joints of the other leg (Table 1).

In the growing rabbits the condyles of

the immobilized knee were wider than normal, their structure was more heterogeneous and they were deformed. Higher concentrations of oxytetracycline were found on the immobilized side compared with the normal knee and it was always found to be spread over larger areas. In the distal end of the femur of growing rabbits there is normally a tetracycline marked zone only on the metaphyseal side of the epiphyseal plate, but in the immobilized leg, in three rabbits there was bone marked by tetracycline on the epiphyseal side as well (Figure 1 a b).

In the adult rabbits marked degenerative changes were seen in the immobilized knees. The condyles were thicker than normal slightly deformed and their structure was more heterogeneous than normal. Oxytetracycline was found over larger areas especially at the periphery, and in general in higher concentrations than in the left knee (Figure 2 a, b). These changes occurred in seven of the nine rabbits given oxytetracycline just before they were killed. In two of the four adult rabbits given oxytetracycline at the beginning of the immobilization period only, the oxytetracycline content was higher in the left knee than in the immobilized right knee.

Marked changes were also seen in the hip joints of the immobilized hind legs of the rabbits. The capsule was considerably thickened and the cartilage had degenerated. The cartilage and bone alterations were generally less severe than in the knee joints. In some hips however, noticeable alterations were seen in the head and neck of the femur, where the oxytetracycline content was also higher and covered larger areas than in the hip joint of the non immobilized leg (Figure 3 a b). These changes occurred in 15 of the 20 rabbits given oxytetracycline 1-13 days before they were killed. In two of the three rabbits examined and given oxytetracycline at the beginning of the immobilization period the oxytetracy-

cline content was higher in the left hip than in the right.

DISCUSSION

In which tissues and at what time the various alterations take place when osteoarthritis develops has not been satisfactorily explained. Since it is difficult to study the initial stages of osteoarthritis in humans studies of experimentally induced arthritis in animals have been commenced. In the studies of other investigators, experimental osteoarthritis has mostly been produced by trauma and has therefore been accompanied by tissue damage. In this series immobilization was used in order to produce osteoarthritis without immediate tissue damage. In our experiments the knee only was immobilized in extension while the hip was left free. Degenerative alterations were consistently produced in the knee as a direct consequence of immobilization, but also in the hip of the same leg marked degenerative alterations were sometimes seen even though it was not immobilized.

We have previously reported that in adult rabbits knee immobilization simultaneously increases the uptake of ^{35}S -sulphate in the joint capsules of the knee and hip, and in the cartilage and bone tissue (Videman et al 1975, 1976). The oxytetracycline content was usually higher in the right immobilized knee and hip in the rabbits given oxytetracycline just before they were killed, but in the non immobilized knee and hip of the rabbits given oxytetracycline at the beginning of immobilization. This indicates an increased turnover of the bone tissue in the immobilized leg compared with the other leg.

This study increases our understanding of how bone tissue reacts during immobilization and the development of osteoarthritis.

Table 1 Content of oxytetracycline in knee and hip of the immobilized (right) leg compared with the left non immobilized knee and hip in 20 rabbits. The oxytetracycline was given some days before the animals were killed

Rabbit no	Age at immobilization in months	Duration of immobilization in weeks	Interval between immobilization and sacrifice in weeks	Oxytetracycline content in right knee	in right hip
Growing rabbits					
295	3	5	8	++	+
411	3	6	1	++	+
412	3	6	1	+	++
220	4	6	28	-	+
223	4	6	30	++	+++
398	5	6½	0	+	+
387	5	7	0	+++	+
389	5	7	2	++	+
388	5	8½	4	++	+
392	5	8½	11	++	++
225	2	13	1	++	+
Adult rabbits					
395	> 12	2	1	+	+
66	12	4	52	+	+
80	9	5	78	-	-
401	> 12	7	0	+++	+
10	> 12	8½	52	+	-
375	13	13	34½	+	-
230	33	13	26	++	-
811	11	17½	1	-	-
303	16	17½	2	++	+

— not more oxytetracycline in the right (immobilized) joint than in the left
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(Jangenskiöld 1972 b; Michelsson & Jangenskiöld 1974)

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In the growing rabbits the condyles of

REFERENCES

- Evans J H, Eggers G W N, Butler, J R & Blumel J (1960) Experimental immobilization and remobilization of rat knee joints *J Bone Jt Surg* 42 A 737-758
- Frust H W, Villanueva A R & Roth H (1960) Measurement of bone formation in a 57 year old man by means of tetracyclines *Henry Ford Hosp Bull* 239 244
- Hall M C (1963a) Articular changes in the knee of the adult rat after prolonged immobilization in extension *Clin Orthop* 34 231-193
- Hall M C (1963b) Cartilage changes after experimental immobilization of the knee joint of the young rat *J Bone Jt Surg* 45-A 36-44
- Langenskiöld A, Michelsson J F & Videman T (1975) Osteoarthritis of the knee in the rabbit produced by immobilization *Scand J Rheum Suppl* 8 7-8
- Michelsson J F & Langenskiöld A (1972a) Dislocation of the hip and coxa vara following immobilization of the knee in extension in young rabbits *Scand J clin Lab Invest* 24 Suppl 122 50
- Michelsson J F & Langenskiöld A (1972b) Dislocation or subluxation of the hip. Regular sequelae of immobilization of the knee in extension in young rabbits *J Bone Jt Surg* 54 A 1177-1186
- Michelsson J F & Langenskiöld A (1974) Coxa vara following immobilization of the knee in extension in young rabbits *Acta orthop scand* 43 399-411
- Michelsson J F, Videman T & Langenskiöld A (1977) Contractures of the knee in provoking osteoarthritis in rabbits by immobilization *IRCS Med Sci* 5 61
- Mitch H A, Rall, D P & Tobie, J E (1957) Bone localization of the tetracyclines *J nat Cancer Inst* 19, 87-93
- Salter, R B & Field, P (1950) The effects of continuous compression on living articular cartilage. An experimental investigation *J Bone Jt Surg* 42 A, 31-49
- Saltzman A (1950) Fluorophotometric estimation of Aureomycin in blood and urine *J Lab clin Med* 36 123-128
- Telhag H & Lindberg L (1972) A method for inducing osteoarthritic changes in rabbits' knees *Clin Orthop* 86 214-223
- Trias A (1961) Effect of persistent pressure on the articular cartilage. An experimental study *J Bone Jt Surg* 43 B, 376-386
- Videman T, Michelsson J-E & Rauhamaki, R (1975a) The initial changes in ground substance formation of different tissues in experimental osteoarthritis studied by ³⁵S-sulphate *Scand J Rheum Suppl* 8, 7-9
- Videman T, Michelsson J E, Rauhamaki, R & Langenskiöld, A (1976) Changes in ³⁵S sulphate uptake in different tissues in the knee and hip regions of rabbits during immobilization, remobilization and the development of osteoarthritis *Acta orthop scand* 47, 290-298
- Videman T, Michelsson J E & Langenskiöld, A (1977a) The development of radiographic changes in experimental osteoarthritis provoked by immobilization of the knee in rabbits *IRCS Med Sci* 5 62.
- Videman T, Langenskiöld, A, Michelsson J E & Candolin, T (1977b) A macroscopic and scanning electron microscopic study of experimental osteoarthritis of the knee *IRCS Med Sci* 5 232-233

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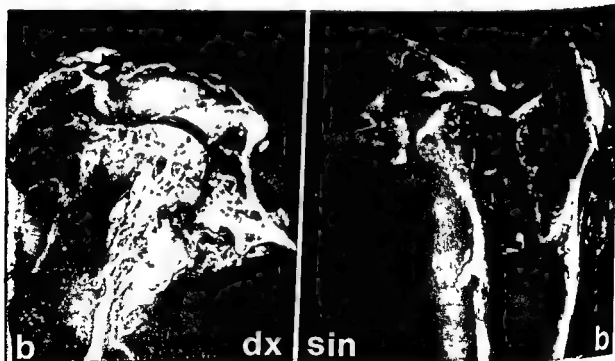
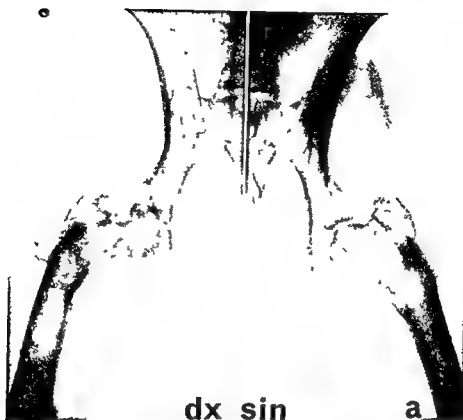


Figure 3 a b A 4 month old rabbit (223) was immobilized with the right knee in extension for 6 weeks. Seven months later the animal was given oxytetracycline and killed. a) Degenerative changes are clearly visible on the radiograph of the right hip. b) Increased content of oxytetracycline as a sign of increased bone formation in the specimen of the right hip.

Table 1 Pre and postoperative data of the 31 patients

Case	Age	Site	History and duration of ankylosis (years)	Initial	Range of motion (extent in flexion) 3 months after operation	At the time of follow up	Evaluation	Length of follow up (years)
1	15	r	Fracture	50	20-105	30-105	Good	5
2	19	r	Tuberculosis	75	45-87	60	Poor	17
3	19	r	Fracture	70	50-115	50-135	Good	16
4	24	r	Fracture	90	35-105	15-145	Excellent	7
5	25	r	Fracture	90	30-110	20-140	Excellent	7
6	21	r	Dislocation	50	50-100	70-95	Poor	21
7	21	r	Fracture	55-80	50-100	20-115	Excellent	21
8	20	r	Fracture	10-50	50-115	60	Poor	20
9	25	r	Dislocation	15-70	70-70	70	Poor	10
10	25	r	Tuberculosis	80	75-110	65-110	Fair	22
11	23	r	Tuberculosis	80	35-105	50-90	Fair	22
12	26	r	Fracture	35-80	40-120	40-120	Good	24
13	22	r	Fracture	5	25-85	30-90	Fair	18
14	23	r	Dislocation	30	75-100	55-115	Fair	30
15	29	r	Dislocation	45-70	60-100	50-90	Fair	24
16	40	r	Fracture	45-75	50-100	55-110	Fair	27
17	10	r	Fracture	90	65-82	85	Poor	25
18	11	r	Fracture	81	30-130	20-110	Excellent	28
19	41	r	Fracture	45	25-50	35-50	Poor	30
20	15	r	Fracture	50-70	20-110	70-115	Fair	31
21	33	r	Fracture	50	35-100	20-110	Good	0
22	32	r	Fracture	55	35-110	30-120	Excellent	9
23	32	r	Fracture	55	35-120	30-100	Excellent	10
24	21	r	Fracture	50-70	35-95	15-90	Fair	11
25	19	r	Dislocation	20	40-70	20-125	Good	9
26	31	r	Dislocation	20	20-90	30-120	Excellent	9
27	32	r	Dislocation	70	50-100	40-110	Good	25
28	15	r	Fracture	40-80	50-100	70-100	Good	26
29	18	r	Fracture	75	65-90	60-100	Fair	23
30	12	r	Fracture	50	70-75	40-130	Fair	22
31	20	r	Osteochondromatosis	20-35	50-130	40-130	Excellent	22
Average	27			50-59	42-103	43-105		19

ARTHROPLASTY OF THE ELBOW USING J-K MEMBRANE

An Analysis of 31 Cases

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A study of the end results of arthroplasty of the elbow has been made. 31 cases were evaluated clinically and roentgenographically an average of 19 years after operation. The arthroplasty was performed with a minimum of bone resection using chromicized fascia lata (J-K membrane) as an interposition. The maximum range of motion was regained within 3 months and was maintained during the follow-up period. No patient in this series suffered from pain or instability of the joint though radiological signs of osteoarthritis were common.

Key words: arthroplasty of the elbow, J-K membrane

Accepted 7 vi 77

Restriction of movement and pain in the elbow joint are a cause of disability at work and limitation of daily activity. Arthrodesis is unsatisfactory from the functional and cosmetic points of view.

Various arthroplastic procedures have been devised in an attempt to improve these conditions, since the first success of Verneuil (1860), and the subsequent description of the principles of arthroplasty by Ollier (1885), Murphy (1913), and Campbell (1931). Due to the rapid development of the various types of endoprostheses, classical methods of arthroplasty have been abandoned in recent years. Nevertheless, the elbow still remains the joint most suited for arthroplasty without a prosthesis, because it bears little weight and the pattern of movement is relatively simple.

In Japan, Sumita (1912) carried out experimental studies on arthroplasty and Jinnaka & Kono (1949) utilized chromicized autogenous fascia (named J-K

membrane) as an interposition. They succeeded in diminishing the inflammatory tissue reaction of Baer's membrane (1918) by reduction of the dichromic acid potassium under direct sunlight and washing off of the soluble chromic oxide.

The purpose of the present analysis is to evaluate the long-term results as regards 1) range of motion, 2) functional ability, 3) severity of neurological complications, and 4) roentgenographic changes, in a series of this type of arthroplasty.

PATIENTS AND METHODS

Details of the 31 patients in this series are listed in Table 1. There were eight cases of septic arthritis, fifteen cases of fracture or fracture-dislocation, and seven cases of rheumatoid arthritis.

1) Preparation of J-K membrane

One week before operation, a sheet of fascia 8 x 6 cm is detached from the tensor fascia lata

Table 2 The results of arthroplasty of the elbow classified according to the various aetiologies

Aetiology	Excellent	Good	Fair	Poor	No. of cases
Fracture and/or dislocation	3	5	6	1	15
Septic arthritis		1	3	4	8
Rheumatoid arthritis	5		1	1*	7
Osteochondromatosis	1				1
Total	9	6	10	6	31

Case 8



Figure 4 Case 8 Rheumatoid arthritis a) before b) 2 months and c) 3 years after operation

direction for this type of arthroplasty (Herbert 1958, Hurri et al 1961).

As a general rule, the maximum range of motion was regained within 3 months after the operation and this remained unchanged as time passed. Bone resorption was rarely seen in our patients. Proliferative or hypertrophic bone changes were found quite frequently but never to such an extent that pain or

progressive limitation of motion could be attributed to them. There were no cases of serious instability or subluxation. Pseudoarthrosis of the olecranon was found in four cases but the force of extension was not diminished.

Air arthrography was performed in four cases. The joint cavity had almost normal dimensions (17.5 ml on average) and was bounded by an irregular capsule

muscle of the patient. The fascia is stretched on a frame and kept in a 2 per cent dichromic acid potassium solution at room temperature for 24 hours. Following this it is exposed to direct sunlight or a quartz lamp for 1 or 2 days in order to reduce the dichromic acid. The fascia is then washed in running water for 24 hours. Afterwards it is stored in phenol with the addition of 70 per cent alcohol.

2) Operative technique

A posterior approach is preferred. The olecranon is cut and reflected. A simple monocondylar joint is fashioned by resection of a minimum amount of bone in order to avoid postoperative instability. The humero ulnar joint is reshaped according to the anatomical curvature. The radial head is usually resected at the same level as the ulna. In nine cases reshaping of the radial head was done in order to preserve the pronation supination of the forearm. In four cases transposition of the ulnar nerve was performed.

The coronoid and olecranon fossae are deepened and the end of the humerus is covered by the Jk membrane. Lengthening of the triceps tendon is rarely necessary even when the elbow is ankylosed in full extension.

3) Aftertreatment

The extremity is immobilized for 1 week following which an extension frame is applied (Figure 1). Three weeks after operation pulley exercises are begun in the frame with mild resistance both active and passive.

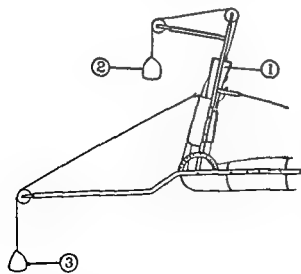


Figure 1 Traction pulley exercise apparatus

1 Skin traction on forearm

2 Weight for traction of forearm

3 Weight for flexion exercises of the elbow

RESULTS

The end results have been graded as follows:

Excellent range of motion from 90 to 120°, with good stability and muscle strength

Good range of motion from 70 to 90° with satisfactory stability and sufficient strength for everyday activities

Fair range of motion from 40 to 70° without instability, or adequate range of motion with instability

Poor range of motion less than 40° and/or gross instability

The results classified according to the various etiologies are shown in Table 2.

In 15 cases of fracture and fracture-dislocation one failure was due to postoperative infection. The results were very diverse in this group perhaps because the deformity of the humeral condyle makes it difficult to judge the optimal amount of bone resection. Soft tissue damage following open fracture is also an undesirable factor.

The results in eight cases of septic arthritis were almost entirely unsatisfactory. Only one case was evaluated as good.

Among seven cases of rheumatoid arthritis one failure was due to fracture of the humerus 5 months after the operation (Case 8). The elbow was immobilized for 2 months as a consequence of which bony ankylosis developed. Apart from this case the results for this condition are most encouraging in spite of extensive joint involvement (Figure 2). The disease was quiescent at the time of operation and no exacerbation of the arthritic process followed. Arthroplasty of both elbows was performed in two patients and the results were satisfactory. Less resorption of bone was found in the rheumatoid cases in comparison to the other groups. In general rheumatoid arthritis was considered to be the best in

ular joint were performed in nine cases with the result that a rotational movement of more than one half of the normal range was obtained in six cases.

The advantage of the J-K membrane is that apparently it produces less adhesions in the newly established joint compared with the other kinds of interposition (Putti 1920, McAusland 1921, Nagayama et al 1971), and also it permits a minimal amount of bone resection.

In our opinion this classical arthroplasty of the elbow is well worth trying because it results in a stable joint with a useful range of mobility and freedom from pain. Endoprosthesis should be reserved for the rare cases with pronounced bone destruction and very unstable joints.

It can be concluded that arthroplasty of the elbow using J-K membrane, properly performed in selected cases, offers a useful range of motion with good stability and strength. It is indicated for patients between 15 and 60 years of age, when functional disability is the result of rheumatoid arthritis and fracture or fracture dislocation of the elbow joint.

ACKNOWLEDGMENTS

The author wishes to express his gratitude to Professor Mitsuo Nishio and Assistant Professor Akira Kobayashi for their support and helpful suggestions.

REFERENCES

- Baer W S (1915) Arthroplasty with the aid of animal membrane. *Amer J orthop Surg* 16: 171-192.
- Campbell W C (1922) Arthroplasty of the elbow. *Ann Surg* 76: 615-623.
- Campbell W C (1931) The physiology of arthroplasty. *J Bone Jt Surg* 13: 223-243.
- Campbell W C (1924) Mobilization of joint with bony ankylosis. *J Amer med Ass* 27: 976-981.
- D'Aubigné, R M & Kerboul, M (1966) Les opérations mobilisatrices des raideurs et ankyloses du coude. *Rev Chir orthop* 52: 427-443.
- Hass J (1944) Functional arthroplasty of elbow and knee. The American Academy of Orthopaedic Surgeons Instructional Course Lectures Vol 2, p 340.
- Herbert J J (1958) Traitement des ankyloses du coude dans le rhumatisme. *Rev Chir orthop* 44: 87-90.
- Hurri L, Pulkki T & Vainio H (1964) Arthroplasty of the elbow in rheumatoid arthritis. *Acta chir scand* 127: 459-465.
- Jinaka S & Kono S (1949) The arthroplasty (Japanese). Tokyo: Igakushoin.
- Knight R A & van Zandt L L (1952) Arthroplasty of the elbow. *J Bone Jt Surg* 34A: 610-618.
- Ollier L (1883) *Traité des résection et des opérations conservatrices qu'on peut pratiquer sur le système osseux*. G. Masson Paris.
- McAusland W R (1921) Mobilization of the elbow by fascia transplantation with report of thirty one cases. *Surg Gynec Obstet* 33: 223-245.
- Murphy J B (1915) Arthroplasty. *Ann Surg* 67: 593.
- Nagayama I, Tsuge K, Mochizuki Y & Nakamura Y (1971) On the experience of arthroplasty of the elbow (Japanese). *Orthop Surg* 29: 1110-1117.
- Pemister D B & Miller E M (1924) The method of new joint formation in arthroplasty. *Surg Gynec Obstet* 26: 406-416.
- Putti A (1920) Arthroplasty of the knee joint. *J orthop Surg* 2: 530.
- Sumita M (1912) Experimentelle Beiträge zur operativen Mobilisierung ankylosierter Gelenke. *Arch. Klin. Chir* 92: 755.
- Vernieuw A (1860) De la création d'une fausse articulation par section ou résection partielle de la maxillaire inférieure comme moyen de remédier l'ankylose orale du fausse de la mâchoire inférieure. *Arch gén Méd* 15: 281-316.

(Figure 3) It was not possible to deduce the exact thickness of the articular cartilage. No dispersion of the air to the radioulnar joint was seen.

The roentgenographic changes following arthroplasty do not parallel the functional result. However the irregularity of the joint surfaces, the hypertrophic changes and incongruity of the joint do not cause pain. In fact no patient in this series has suffered from pain in carrying out daily activities.

Ulnar nerve palsy and other neurological disturbances were not found.

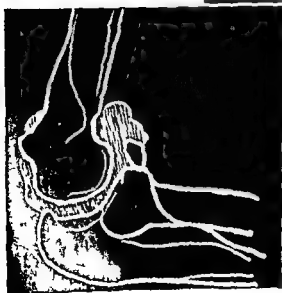


Figure 3 Arthrography of Case 6

DISCUSSION

It appears from our series of patients that the mobility of the elbow remains unchanged in spite of gross roentgenographic changes. However cases with an infectious origin lead to very poor functional results. If this procedure is selected the surgeon should be certain that the inflammatory process has completely subsided. In general it may be stated that previous infection is a contraindication, even though the means available for antibiotic treatment are far better today than they were 30 years ago (Campbell 1922, 1924; Phemister & Miller 1924).

It seems that muscle weakness due to long term loss of mobility is not always irreversible if adequate and sustained muscle training is instituted before and after operation.

The best indication for the arthroplasty is functional disability due to rheumatoid arthritis because in these cases the anatomical shape of the condyle is often preserved. If, on the other hand, excessive bone atrophy is present the procedure is contraindicated.

The amount of bone resection should be determined with the aim of obtaining a balance between good mobility and preservation of a stable joint. The range of motion in this series was not always satisfactory because of a reluctance to remove too much of the end of the humerus when compared with the procedures of Hays (1914), Duboulet & Kerboul (1966) and Hurri et al (1964). This may explain why serious instability due to excessive condylar resorption was not found. We do agree with Knight & van Zandt (1952) who recommended a gap after bone resection of three quarters of an inch. Excessive resection of the radial head should also be avoided. In our series reshaping instead of resection of the radial head and interposition of the J. K. membrane in the proximal radio-

linear joint were performed in nine cases with the result that a rotational movement of more than one half of the normal range was obtained in six cases.

The advantage of the J-K membrane is that apparently it produces less adhesions in the newly established joint compared with the other kinds of interposition (Putti 1920, McAusland 1921, Nagayama et al 1971), and also it permits a minimal amount of bone resection.

In our opinion this classural arthroplasty of the elbow is well worth trying because it results in a stable joint with a useful range of mobility and freedom from pain. Endoprosthesis should be reserved for the rare cases with pronounced bone destruction and very unstable joints.

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REFERENCES

- Baer W H (1918) Arthroplasty with the aid of animal membrane. *Amer J orthop Surg* 16 171-199.
Campbell W C (1972) Arthroplasty of the elbow. *Ann Surg* 76 615-673.

- Campbell W C (1931) The physiology of arthroplasty. *J Bone Jt Surg* 13 223-243.
Campbell W C (1924) Mobilization of joint with bony ankylosis. *J Amer med Ass* 27 976-981.
D'Aubigné, R M & Kerboul, M (1966) Les opérations mobilisatrices des raideurs et ankyloses du coude. *Rev Chir orthop* 52 477-488.
Hass J (1944) Functional arthroplasty of elbow and knee. The American Academy of Orthopaedic Surgeons Instructional Course Lectures Vol 2 p 340.
Herbert J J (1953) Traitement des ankyloses du coude dans le rhumatisme. *Rev Chir orthop* 44 87-90.
Hurri L, Pulkkinen T & Vainio H (1964) Arthroplasty of the elbow in rheumatoid arthritis. *Acta chir scand* 127 459-460.
Iwazaki S & Kono S (1919) The arthroplasty (Japanese). Tokyo Igakushoin.
Knight R A & van Zandt L L (1952) Arthroplasty of the elbow. *J Bone Jt Surg* 34-A 610-618.
Olier L (1833a) *Traité des résection et des opérations conservatrices qu'on peut pratiquer sur le système osseux*. B. Masson Paris.
McAusland W R (1921) Mobilization of the elbow by fascia transplantation with report of thirty one cases. *Surg Gynec Obstet* 33 223-245.
Murphy J B (1913) Arthroplasty. *Ann Surg* 57 593.
Nagayama I, Tsuge H, Nochiyuki Y & Nakamura Y (1971) On the experience of arthroplasty of the elbow (Japanese). *Orthop Surg* 22 1110-1117.
Phemister D B & Miller E M (1924) The method of new joint formation in arthroplasty. *Surg Gynec Obstet* 26 405-446.
Putti V (1920) Arthroplasty of the knee joint. *J orthop Surg* 2 530.
Sumita M (1912) Experimentelle Beiträge zur articulation par section ou résection partielle de los maxillaire inferieur comme moyen de remédier l'ankylose orale du fausse de la mâchoire inferieur. *Arch gen Méd* 15 254-316.

(Figure 3). It was not possible to deduce the exact thickness of the articular cartilage. No dispersion of the air to the radioulnar joint was seen.

The roentgenographic changes following arthroplasty do not parallel the functional result. However, the irregularity of the joint surfaces, the hypertrophic changes and incongruity of the joint do not cause pain. In fact, no patient in this series has suffered from pain in carrying out daily activities.

Ulnar nerve palsy and other neurological disturbances were not found.



Figure 3 Air arthrography of Case 26

DISCUSSION

It appears from our series of patients that the mobility of the elbow remains unchanged in spite of gross roentgenographic changes. However, cases with an infectious origin lead to very poor functional results. If this procedure is selected, the surgeon should be certain that the inflammatory process has completely subsided. In general it may be stated that previous infection is a contraindication, even though the measures available for antibiotic treatment are far better today than they were 30 years ago (Campbell 1922, 1924, Phemister & Mill 1924).

It seems that muscle weakness due to long-term loss of mobility is not always irreversible if adequate and sustained muscle training is instituted before and after operation.

The best indication for the arthroplasty is functional disability due to rheumatoid arthritis, because in these cases the anatomical shape of the condyle is often preserved. If, on the other hand, excessive bone atrophy is present, the procedure is contraindicated.

The amount of bone resection should be determined with the aim of obtaining a balance between good mobility and preservation of a stable joint. The range of motion in this series was not always satisfactory because of a reluctance to remove too much of the end of the humerus, when compared with the procedures of Hass (1944), D'Aubigné & Kerboul (1966) and Hurri et al (1964). This may explain why serious instability due to excessive condylar resorption was not found. We do agree with Knight & van Zandt (1952) who recommended a gap after bone resection of three-quarters of an inch. Excessive resection of the radial head should also be avoided. In our series, reshaping instead of resection of the radial head and interposition of the J-K membrane in the proximal radio-



Figure 2 A Hypertrophic pseudarthrosis



Figure 2 B Operation performed

is applied postoperatively for a couple of weeks, and passive mobilisation exercises of the shoulder joint are started immediately. All the patients were re-examined from 10 to 23 months after the operation.

RESULTS AND DISCUSSION

During the follow up period, the cases operated were examined both clinically and radiologically, and complete healing was demonstrated in all patients. A typical pseudarthrosis before and after treatment is shown in Figure 2. The treatment described above for clavicular pseudarthrosis has yielded excellent results, has proved to be simple to perform, and has been without any complications.

REFERENCES

- Apley, A. G. (1968) *A system of orthopaedics and fractures* 3rd ed. p. 409, Butterworths, London.
- Carphoff, H. (1968) Non union of the clavicle. *J. Amer. med. Ass.* 172 1006-1011.
- Hone, C. R. (1968) An atlas of anatomy and treatment of midclavicular fractures. *Clin. Orthop.* 58 29-42.
- Sakellarydes, H. (1961) Pseudarthrosis of the clavicle. *J. Bone Jt. Surg.* 43 A, 130-138.
- Watson Jones, R. (1960) *Fractures and joint injuries* Vol. 2, 4th ed., p. 462 F & S Livingstone Ltd, Edinburgh.

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TREATMENT OF POSTTRAUMATIC CLAVICULAR PSEUDARTHROSIS

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Six patients with posttraumatic pseudarthrosis of the clavicle were treated during 1973 and 1974 with an operative technique consisting of trimming of the bone ends, placement of a cortical bone transplant posteriorly and a metal plate anteriorly, and fixation of the plates with screws. At examination 10-23 months postoperatively complete healing had been achieved in all cases.

Key words: clavicle fractures, pseudarthrosis surgery

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Development of a pseudarthrosis after clavicular fracture is uncommon regardless of treatment, but it seems to occur more frequently after primary operative than after conservative treatment (Watson-Jones 1960, Apley 1968). Neer (1960) reports the incidence of pseudarthrosis after clavicular fracture to be 0.1 per cent after conservative treatment, and 4.4 per cent after operative treatment in a material of 2235 conservatively treated and 45 operated patients. Rowe (1968) reports the incidence as 0.8 and 3.7 per cent, respectively.

PATIENTS AND METHODS

During the years 1973 and 1974 six patients with posttraumatic clavicular pseudarthrosis presented for treatment. Half of the patients were younger than 20 years on admission, the oldest one being 57 years. Five were males and one was a female. Three had a right-sided and three a left-sided fracture. The time interval between fracture and pseudarthrosis operation varied between 6 months and 3 years. The reason for the long interval in some cases was lack of trouble

some symptoms as also pointed out by Campbell (1971) and Salcellarides (1961).

The operative technique applied was introduced by the late Professor Alvik (personal communication 1965). The bone ends are trimmed, a cortical bone transplant is modelled in the form of a plate and placed on the superior posterior aspect of the clavicle, and a 4-6 hole metal plate is placed on the inferior anterior aspect. The medullary side of the transplant faces the clavicular cortex after roughing of the latter with a chisel. Screws from the metal plate fasten both plates to the clavicle and secure a rigid fixation. A schematic presentation of the technique is given in Figure 1.

The choice of bone for transplantation was determined by the demand for strength and the availability of bone. In three cases a homotransplant of tibia sponge from the bone bank was used, while in the remaining cases autotransplants from the tibial crest were used. Autella



Figure 1 Principle of fixation. Screws from the metal plate pass through the clavicle and the bone transplant.



Figure 2 A Hyperplastic pseudarthrosis



Figure 2 B Operation performed

is applied postoperatively for a couple of weeks and passive mobilisation exercises of the shoulder joint are started immediately. All the patients were re-examined from 10 to 23 months after the operation.

RESULTS AND DISCUSSION

During the follow up period, the cases operated were examined both clinically and radiologically, and complete healing was demonstrated in all patients. A typical pseudarthrosis before and after treatment is shown in Figure 2. The treatment described above for clavicular pseudarthrosis has yielded excellent results and has proved to be simple to perform and has been without any complications.

REFERENCES

- Apley A G (1968) *A system of orthopaedics and fractures* 3rd ed. p. 409 Butterworths London
- Campbell's operative orthopaedics (1971) Vol 1 5th ed Ed Speed J S & Knight R A p. 804 The C V Mosby Co Saint Louis
- Neer C S (1960) Non union of the clavicle *J Amer med Ass* 172 1006-1011
- Rowe C R (1968) An atlas of anatomy and treatment of midclavicular fractures *Clin Orthop* 58 29-42
- Sakellariades H (1961) Pseudarthrosis of the clavicle *J Bone Jt Surg* 43 A 130-133
- Watson Jones R (1960) *Fractures and joint injuries* Vol 2 4th ed. p. 462 J & S Livingstone Ltd Edinburgh

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SPINAL NERVE BLOCK

A Diagnostic Test in Sciatica

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The cause of sciatica has been studied by blocking spinal nerves of the lumbosacral plexus in intervertebral foramina. The nerve, which is singled out with the aid of an image intensifier, is injected with 1 ml of 1 per cent Xylocain. If the Xylocain injection eliminates the sciatic pain, the surgeon may be confident that a true nerve root compression is involved, and he can then explore as far as he finds necessary. The correlation between the site of compression and the level indicated by the test was confirmed by operation in 19 patients.

Key words: anaesthesia, local, sciatica, diagnosis, aetiology, intervertebral disc displacement, diagnosis.

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Surgery has been a valuable method of treating sciatica since Mixter & Barr (1934) demonstrated the role that the rupture of an intervertebral disc plays in its aetiology. In order to plan the operation correctly, it is essential to determine the particular nerve root from which the patient's symptoms arise. Neurological signs have proved to be somewhat inaccurate for assessment of the level of disc herniation (Troupp & Ulfves 1959, Knutsson 1961). Myelography appears to be a more reliable means for the determination of the vertebral level (Karaharju et al 1974). However, a false negative result of myelography is a possibility and in cases of previous laminectomy the interpretation of positive findings may be difficult. Consequently, some other method of examination would be of value.

Injection of local anaesthetic has been recommended as a useful test in this re-

spect (Maenab 1971, Schultz et al 1973, Krempe & Smith 1974). An essential part of this technique has been to inject contrast medium into the root sleeve in order to confirm the proper positioning of the needle. This is followed by the injection of a local anaesthetic, which will eliminate sciatic pain if the cause of pain is to be found somewhere along the course of this particular nerve root. We have carried out this test without contrast medium.

PATIENTS AND METHODS

The patient lies in the prone position with a cushion under the lower abdomen to bring the sacrum as close to the horizontal level as possible. With the aid of an image intensifier a lumbar puncture needle is inserted towards the lateral part of the intervertebral foramen and moved cautiously until the patient experiences a sharp stab of sciatic pain. If the first sacral

Table 1 Myelographic and operative findings in patients in whom the level of spinal nerve compression was localized by a positive nerve block test

Spinal nerve compressed	Disc prolapse + Myelogram +	Disc prolapse + Myelogram -	Disc prolapse - Myelogram -	Total
L III	-	-	1	1
L IV	-	-	-	-
L V	4	-	7	11
S I	1	2	1	7
	5	2	12	19

nerve is to be tested the needle must be inserted into the first sacral foramen. In this way it will be possible to ascertain which of the spinal nerves produces the patient's typical pain. Following this 1 ml of 1 per cent Xylocain is then injected into this nerve. Relief of symptoms will follow in a few minutes. Should a previously positive Lasague test become negative care must be taken in testing straight leg raising because there is a risk that the anesthetized nerve root may be overstretched (Langenskiöld 1975).

This test has to date been used on 22 patients. In 19 of them 11 men and 8 women mean age 41 years, operation confirmed that a positive test had identified the actual nerve subject to compression (Table 1).

The cause of compression was a herniated disc in seven patients. In five of these the injection test correlated with a positive myelogram, the prolapse being found at the L IV V level in four patients and at the lumbosacral level in one. In two patients with a negative myelogram a herniation was found to be compressing the nerve root which the nerve block had identified as being affected. The intervertebral space was L V S I in both cases.

In 12 patients with a negative myelogram no herniated disc was found at operation but the level of compression had been correctly identified by the nerve block. The cause of compression was traced back to a bony entrapment of the intervertebral foramen.

In the 12 patients with a negative myelogram no herniated disc was found at operation but the level of compression had been correctly identified by the nerve block. The cause of compression was traced back to a bony entrapment of the intervertebral foramen. In 12 patients with a negative myelogram no herniated disc was found at operation but the level of compression had been correctly identified by the nerve block. The cause of compression was traced back to a bony entrapment of the intervertebral foramen. In 12 patients with a negative myelogram no herniated disc was found at operation but the level of compression had been correctly identified by the nerve block. The cause of compression was traced back to a bony entrapment of the intervertebral foramen.

DISCUSSION AND CONCLUSIONS

It has been recommended that the correct position of the needle should be first confirmed by an injection of contrast medium (Macnab 1971, Krempen & Smith 1974). If the needle is not in the root sleeve, the sinuvertebral nerve may be anaesthetized resulting in an incorrect evaluation of the sciatic problem (Krempen & Smith 1974). When the needle is inserted in the manner described above, it is intended to enter the spinal nerve beyond the dural sheath. Owing to the anatomy of this region (Pedersen et al 1956), it is possible that both the sinuvertebral nerve, which passes through the intervertebral foramen, and the posterior ramus of the spinal nerve will be anaesthetized. However, this need not lead to a mistaken judgement, since the sinuvertebral nerve supplies the ventral dura and the posterior longitudinal ligament and according to observations made during disc operations, under local anaesthesia pain originating in these structures has solely a lumbosacral and not a sciatic character (Wiberg 1950). Such an injection may also suppress the pain that originates in the area of the first posterior branch of the spinal nerve. Although this kind of pain may radiate to the lower extremity, it should be distinguishable, by the absence of neurological signs, from radiating pain due to nerve-root compression (Steindler & Luck 1938, Sutcliffe et al 1948). To pre-

vent an aesthesia from spreading into the spinal canal, only 1 ml Xylocain should be injected.

Our experience has shown that spinal nerve block in the lumbosacral region is a valuable test even without the information obtainable by contrast-medium injection. The techniques involved no complications or difficulties. We recommend this test for use whenever the level of nerve root compression is uncertain, particularly when the myelogram is negative or difficult to interpret and compression at foraminal level is suspected.

REFERENCES

- Karaharju M, O. Alho A & Laasonen J (1974) Herniated lumbar disc: postoperative condition and correlation with preoperative and operative findings. *Ann Chir Gynaec Fenn* 63: 53-56.
- Knutsson B (1961) Comparative value of electromyographic, myelographic and clinical neurological examinations in diagnosis of lumbar root compression syndrome. *Acta orthop scand* Suppl. 49.
- Krempen J F & Smith B S (1974) Nerve root injection: A method for evaluating the etiology of sciatica. *J Bone Jt Surg* 56 A: 1439-1444.
- Langenskiöld A (1975) Personal communication.
- Macnab I (1971) Negative disc exploration. *J Bone Jt Surg* 53 A: 891-903.
- Pedersen H F, Blumck C F J & Gärner F (1956) The anatomy of lumbosacral posterior rami and meningeal branches of spinal nerves (sensu vertebral nerves). *J Bone Jt Surg* 38 A: 377-391.
- Schutz H, Loughheed W M, Wortzman G & Awerbrud B K (1973) Intervertebral nerve root in the investigation of chronic lumbar disc disease. *Canad J Surg* 16: 217-221.
- Smelcer D C, Feindel W H, Weddel G & Falender W A (1948) The intervertebral ligaments as source of segmental pain. *J Bone Jt Surg* 30 B: 515-521.
- Steindler A & Luel J V (1938) Differential diagnosis of pain low in the back. *J Amer med Ass* 110: 106-113.
- Troupp H & Ulfvén A (1959) Niddiagnostik vid lumbala distibrål. *Nord Med* 63: 1144-1150.
- Wiberg G (1950) Back pain in relation to the nerve supply of the intervertebral disc. *Acta orthop scand* 19: 211-221.

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INFANTILE AND ADOLESCENT IDIOPATHIC SCOLIOSIS IN THE SAME INDIVIDUAL

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A patient with an infantile, resolving type of idiopathic scoliosis is presented. By the age of 10 years, 4 years after complete spontaneous correction, the girl had developed a structural, progressive idiopathic scoliosis to the opposite side.

Key words: scoliosis infantile adolescent, idiopathic

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There are great differences between the infantile and the adolescent type of idiopathic scoliosis. In the early onset group boys predominate, the curve is usually to the left, and in most cases the scoliosis resolves (James et al 1959, Lloyd-Roberts & Pilcher 1965). A great geographical variation in incidence is found, and there are strong indications that environmental factors are acting in this type of scoliosis (Wynne-Davies 1968, 1975, James 1973). In the adolescent group five out of six cases are females, the curve is usually to the right, and it tends to progress during the entire growth period.

However, the infantile and adolescent types of idiopathic scoliosis are often found in the same family, and therefore, in spite of the differences, Wynne-Davies (1968-1973) held the opinion that both share the same basic etiology.

Lloyd Roberts & Pilcher (1965) stated that no fully resolved curve ever deteriorates. The purpose of the present paper is to present a patient with an infantile idiopathic scoliosis which resolved and who later on developed a curve to the op-

posite side. We have not come across any similar case in the medical literature.

CASE REPORT

The patient is a girl born 16 September 1959. Pregnancy and delivery were normal. A few months after birth the parents noticed a deformity of her spine. The girl was seen at our hospital for the first time when 1 year old. She presented with a left sided thoracic scoliosis and a rib hump on the same side. X-ray showed a thoracic curve measuring 32° extending from T8 to L1 with distinct rotation and apex at T10-11. Compensatory curves were present above and below, and the difference in rib angle was 12° (Figure 1a). Examination revealed no

followed up at half yearly intervals. At the age of 2 years and 6 months the curve was 33° (Figure 1b). One year later it had decreased spontaneously to 20° (Figure 1c), but still the patient presented with an obvious rib hump. The curve improved further, at 4 years and 6 months it measured 12° (Figure 1d), and at 6 the spine was straight.

The patient was still followed up at regular intervals. At 10 a slight curvature to the right side was found, and when 12 years old she presented with an obvious structural scoliosis

vent anaesthesia from spreading into the spinal canal, only 1 ml xylocain should be injected.

Our experience has shown that spinal nerve block in the lumbosacral region is a valuable test even without the information obtainable by contrast-medium injection. The techniques involved no complications or difficulties. We recommend this test for use whenever the level of nerve root compression is uncertain, particularly when the myelogram is negative or difficult to interpret and compression at foraminal level is suspected.

REFERENCES

- Karaharju F O, Alho A & Ijasanen J (1974) Herniated lumbar disc: postoperative condition and correlation with preoperative and operative findings. *Ann Chir Gynaec Fenn* 63 53-56.
- Knutsson B (1961) Comparative value of electromyographic, myelographic and clinical neurological examinations in diagnosis of lumbar root compression syndrome. *Acta orthop scand* 31 suppl 49.
- Krempen J I & Smith H S (1974) Nerve root injection: A method for evaluating the etiology of sciatica. *J Bone Jt Surg* 56 A 143-144.
- Längenskiöld A (1975) Personal communication.
- Macnab I (1971) Negative disc exploration. *J Bone Jt Surg* 53 A 891-903.
- Pedersen H I, Blumel C I J & Gardner I (1956) The anatomy of lumbosacral posterior rami and meningeal branches of spinal nerves (sinu vertebral nerves). *J Bone Jt Surg* 38 A 377-391.
- Schutz H, Loughwell W M, Worlzman C & Awerbrud B K (1973) Intervertebral nerve root in the investigation of chronic lumbar disc disease. *Canal J Surg* 16 217-221.
- Sinclair D C, Leindel W H, Weddel C & Falconer M A (1948) The intervertebral ligaments as source of segmental pain. *J Bone Jt Surg* 30 B 515-521.
- Steindler A & Luck J A (1938) Differential diagnosis of pain low in the back. *J Amer med* 111 106-113.
- Troupp H & Ulfvies A (1959) Nivådiagnostik vid lumbala distalbrål. *Nord Med* 62 1144-1150.
- Wäberg G (1960) Back pain in relation to the nerve supply of the intervertebral disc. *Acta orthop scand* 19 211-221.

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is not demonstrable in this case and there is no indication of environmental factors.

In Norway we have a rather low incidence of infantile idiopathic scoliosis compared with the figures from Great Britain given by Wynne-Davies (1968), Rischborough & Wynne-Davies (1973) and James (1975). In the past few years we

have treated only one or two cases per year at Sophies Minde Orthopaedic Hospital, where most cases of scoliosis from all over Norway have been treated up till now. For comparison, at the same hospital, we treat about 100 new cases of juvenile and adolescent idiopathic scoliosis yearly.

If, as stated, all types of idiopathic



Figure 1 Left-sided resolving type of infantile idiopathic scoliosis in a girl, at 1 year (a) at 1.5 years (b) at 3 years (c) and at 4 years (d) of age

with convexity to the right side, measuring 18° and extending from T6 to L2 with apex at T11-12 (Figure 2 a). One year later the curve had increased to 24° (Figure 2 b) and treatment with a Milwaukee brace was started. She matured at sixteen, her height was then 164 cm, and the curve 28° (Figure 2 c).

DISCUSSION

The first episode of spinal deformity of the case presented was typical for an infantile idiopathic scoliosis of the resolving type. The second curve, occurring about the age of 10, 4 years after complete recovery of the first, is a typical adolescent idiopathic scoliosis. Heredity



is not demonstrable in this case and there is no indication of environmental factors.

In Norway we have a rather low incidence of infantile idiopathic scoliosis compared with the figures from Great Britain given by Wynne-Davies (1968), Riseborough & Wynne-Davies (1973) and James (1975). In the past few years we

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If, as stated, all types of idiopathic



Figure 2 X rays of the same girl as in Figure 1, at 12 years (a) at 13 years (b) and at 16 years (c) of age. She has now developed a right sided progressive type of idiopathic scoliosis.

scoliosis have the same underlying genetic influence it is really not surprising that we may see early and late onset scoliosis in the same individual. The environmental triggering factors supposed to act in adolescence may also affect patients who at an early age have had a resolving type of infantile scoliosis. In

countries where this type of scoliosis is frequent, one might perhaps expect more cases like the one presented here, if in infantile and adolescent idiopathic scoliosis share the same basic etiology.



REFERENCES

- James J I P (1973) The etiology of idiopathic scoliosis. In *Scoliosis* Ed Robin G C. pp 3-8 Academic Press Inc New York and London
- James J I P (1975) The management of infants with scoliosis. *J Bone Jt Surg* 57 B 422-429
- James J I P, Lloyd Roberts H C & Pilcher H F (1959) Infantile structural scoliosis. *J Bone Jt Surg* 41 B 719-730
- Lloyd Roberts H C & Pilcher H F (1965) Structural idiopathic scoliosis in infancy. A study of the natural history of 100 patients. *J Bone Jt Surg* 47 B 520-523
- Riseborough E J & Wynne Davies R (1973) A genetic survey of idiopathic scoliosis in Boston Massachusetts. *J Bone Jt Surg* 55-A 974-989
- Wynne Davies R (1963) Familial (idiopathic) scoliosis. A family survey. *J Bone Jt Surg* 50 B 24-30
- Wynne Davies R (1973) Genetic aspects of idiopathic scoliosis. *Develop Med Child Neurol* 15 809-811
- Wynne Davies R (1975) Infantile idiopathic scoliosis. Causative factors, particularly in the first six months of life. *J Bone Jt Surg* 57 B 138-142

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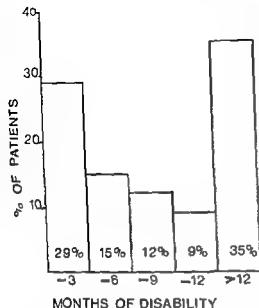


Figure 1 Distribution of 116 patients according to the total duration of postoperative disability

clinical X ray and operative findings, 2) From the Health Insurance Office files all periods of sick leave for low back disorders between 1955 and April 1976 3) From the questionnaire completed at the patient's interview: the evaluation of the whole postoperative course especially in terms of residual symptoms and working capacity

Some patients did not go to work at all after the operation and the total period of disability (the sum of all postoperative sick leave periods) was in these cases regarded as infinite. The presence of patients with an infinite disability

was not used as a basis for comparison between the groups. Instead the method of normal probability graphs (Amador & Hsi 1969) was used separating the whole patient population into two groups: one with a finite duration of disability and one with an infinite duration of disability.

Postoperative disability included 75 patients (65 per cent of the total population). The limits of the "normal" length of total postoperative disability ranged up to 1 year. In 41 patients (55 per cent of the population) this period of disability was longer than 1 year. These patients constituted the other group classified throughout this paper under the heading "extended total duration of disability".

A number of factors were tested against these two groups of patients. The comparison has been made as an item analysis with the different variables examined separately. The chi square test was used as a test of independence between two categories of classification. The indications for the surgical treatment and the surgical technique were standard. As regards the length of the sick leave period only the time period during which the patient's working capacity was diminished, according to the Swedish Health Insurance Office files, was considered. The degree of incapacity (whole or one half incapacity) was disregarded. Sick leave spells shorter than 8 days were also included, despite the fact that medical certificates are not compulsory for such periods. Only diagnoses for low back disorders were considered.

RESULTS

The course of events as regards sick leave for low back troubles

In the group of 116 patients the total number of days spent on sick-leave for low back disorders was followed for 10 years before and 10 years after surgery (Figure 2). It is apparent that the number of days on sick leave increases continually during the whole investigation period and that this is unaffected by surgical treatment. The same trend was also observed when only the number of sick leave periods were investigated. On the other hand, the number of patients with severe recidivous sciatica necessitating hospitalization showed a decreasing trend, being 6 per cent of the whole patient population in the first postoperative year and diminishing subsequently to a constant level of 1 per cent of the whole patient population from the fifth postoperative year.

Preoperative factors influencing total duration of disability (TD)

a) *General characteristics of the patient*. The age and sex were without influence on the TDD. The patients with the "extended" TDD had more often other serious diseases in their past his-

DURATION OF DISABILITY FOLLOWING LUMBAR DISC SURGERY

VALDEMAR V. SURIN

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The total duration of disability of 116 patients operated on for lumbar disc prolapse was studied 10 years postoperatively. From the beginning of the observation period 10 years before surgery, the number of days on sick-leave increased continually and no positive effect of the surgical treatment in this respect could be observed. There was a highly significant coincidence between the end result assessment by the patient and the total duration of the postoperative disability. The following factors were conducive to a short total period of postoperative disability: early surgery (short interval of preoperative sciatica), short total preoperative period of sick leave and immediate relief of sciatic pain by the operation. The objective changes in the preoperative state of the patient such as neurological and X-ray findings had a less significant influence.

Key words: lumbar spine, disc prolapse, surgery, disability

Accepted 7 in 77

The goal of lumbar disc surgery is to relieve pain and disability. From this viewpoint, the long-term course of events as regards sick-leave following surgery is important. Whereas the factors connected with sick-leave in non-operated patients with low back disorders has been the subject of earlier investigations (Westrin 1973), the rare reports on sick-leave in patients operated on for lumbar disc prolapse are based on selected patient populations (Häkeli 1970). To the author's knowledge there are no earlier investigations dealing with the course of events as regards sick-leave in unselected patients operated on for lumbar disc prolapse.

PATIENTS AND METHODS

All patients operated on for suspected lumbar disc herniation during 1964 and 1965 were included in this retrospective study, thus ensuring an equal follow up interval in all investigated patients.

A total of 140 patients were operated on and of this number 129 (92 per cent) could be assessed. This study was made during the year 1976 and the follow up period thus ranged between 10 and 11 years. Thirteen patients who retired during the follow up time were excluded from this part of the investigation, leaving 116 patients. The mean age of the patients at operation was 41.8 years and the ratio men/women was 21/1. The composition of our patient population in this respect compares with previous reports (Spangfort 1972).

The following data were evaluated for each patient: 1) From the medical case record the patient's biographic data, the preoperative and postoperative course of low back disorders, the

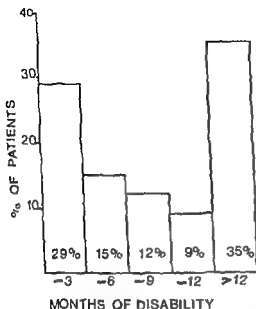


Figure 1 Distribution of 116 patients according to the total duration of postoperative disability

clinical X-ray and operative findings 2) From the Health Insurance Office files all periods of sick leave for low back disorders between 1935 and April 1976 3) From the questionnaire completed at the patient's interview the evaluation of the whole postoperative course especially in terms of residual symptoms and working capacity

Some patients did not go to work at all after the operation and the total period of disability (the sum of all postoperative sick leave periods) was in these cases regarded as infinite. The presence of patients with an infinite disability time and the fact that the total duration of disability was found to form a skewed distribution (Figure 1) invalidated the use of average duration of disability as a basis for comparison between the groups. Instead the method of normal probability graphs (Amador & Ilst 1969) was used separating the whole patient population into two groups according to the total duration of postoperative disability. The one group characterized by a normal total duration of postoperative disability included 75 patients (65 per cent of the total population). The limits of the "normal" length of total postoperative disability ranged up to 1 year. In 41 patients (35 per cent of the population) this period of disability was longer than 1 year. These patients constituted the other group classified throughout this paper under the heading "extended" total duration of disability.

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In the group of 116 patients the total number of days spent on sick leave for low back disorders was followed for 10 years before and 10 years after surgery (Figure 2). It is apparent that the number of days on sick leave increases continually during the whole investigation period and that this is unaffected by surgical treatment. The same trend was also observed when only the number of sick leave periods were investigated. On the other hand, the number of patients with severe recidivous sciatica necessitating hospitalization showed a decreasing trend, being 6 per cent of the whole patient population in the first postoperative year and diminishing subsequently to a constant level of 1 per cent of the whole patient population from the fifth postoperative year.

Preoperative factors influencing total duration of disability (TD)

a) *General characteristics of the patient*. The age and sex were without influence on the TDD. The patients with the extended TDD had more often other serious diseases in their past his-

Table 1 General characteristics of 116 patients related to the total duration of disability (TDD)

Factor	Per cent of patients in the group		Significance
	"Normal" TDD	"Extended" TDD	
Other diseases	24	43	$P < 0.05$
Heavy work	42	66	$P < 0.05$
Mean sum of preoperative sick-leave days	143	232	$P < 0.001$

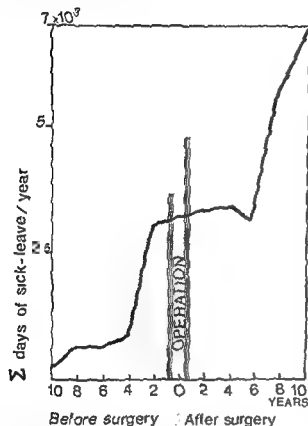


Figure 2 The sum of sick-leave days per year in all 116 patients. Variations during the 10 years before and the 10 years after surgery. Staples sick-leave days immediately before and after surgery

tory, did heavier work preoperatively and were more often and for a longer time on sick-leave for low back disorders during the 10 years prior to surgery (Table 1)

b) The duration of preoperative symptoms. We tried to differentiate between the past history of low back troubles and the duration of the sciatica bout immediately preceding surgery. By "past history" we mean the duration of symptoms from the first onset as opposed to

the defined period preoperatively during which the appearance or deterioration of sciatica developed, in spite of conservative treatment, until surgery was performed. All these estimations are based on autoanamnesis data.

The "long-term history" of low back troubles before operation was sometimes diffuse and any average duration of these troubles was therefore impossible to estimate. Instead the number of patients claiming not to have had previous low back disorders before operation (with the exception of the sciatica bout immediately preceding surgery) were estimated in both groups. It appeared that there were 30 per cent of these patients in the "normal" and 37 per cent in the "extended" TDD group, the difference being not significant. To assess the recall ability of these patients as regards low back disorders, the number of sick-leave spells for a diagnosis of low back disorder during the 10 preoperative years were studied. It appeared that out of 36 patients, 29 (80 per cent) had no such sick-leave spell, five had only one such spell shorter than 2 weeks and only two patients had repeated sick-leave periods totalling 230 days.

The duration of the sciatica bout immediately preceding surgery was stated very precisely by the patients. The mean duration of this sciatica period was 130 days in patients with "normal" and 300 days in patients with "extended" TDD, the difference here being highly significant ($P < 0.001$). Closer analysis revealed (Figure 3), that the TDD was directly proportional to the duration of

Table 2 Operative findings in 116 patients related to the total duration of disability (TDD)

Factor	Per cent of patients in the group		Significance
	"Normal" TDD	Extended TDD	
Complete disc prolapse	40	21	$P < 0.05$
Coincidence of estimated level of nerve root impairment and that found at operation	95	78	$P < 0.01$
Immediate relief of pain after surgery	52	17	$P < 0.001$

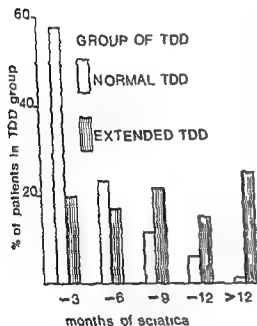


Figure 3 Distribution of the patient groups with normal and extended postoperative duration of disability according to the duration of preoperative sciatica.

immediate preoperative sciatica. It is also interesting to note that the patients operated early (duration of sciatica shorter than 3 months) have the best results when other evaluation criteria (subjective assessment) are considered.

c) *The preoperative state and the X-ray findings* In the group with "normal TDD" 75 per cent of the patients had "legue sign at 4a" as compared with 41 per cent in the group with "extended

TDD, the difference is significant ($P < 0.01$). The severity of nerve root impairment, the level and the side (right or left) of the prolapse were without prognostic significance. The presence and the degree of spondylosis and spondylarthrosis on preoperative X-rays of the lumbar spine were also without predictive value. Sixty one per cent of the total patient population were myelographed. The myelographic pattern of dura indentation was present in 65 per cent of the myelographies of patients with normal and in only 36 per cent of the myelographies of patients with extended TDD, the difference is significant ($P < 0.05$).

d) *The operative findings* The coincidence of the level of nerve root impairment, as estimated preoperatively, with the level found at surgery, the presence of complete disc prolapse and the immediate relief of sciatic pain after surgery are all important prognostic factors (Table 2).

The TDD correlated with the patient's estimation of the end result

The patients' assessment of the operative result 10 years after surgery coincides very well with the total duration of postoperative disability (Table 3), as was expected. But it is important to note in this regard that this coincidence was valid in our patient population only for the sum of all sick leave periods over the 10 years of postoperative follow-up, while

the length of the solitary sick-leave spell, following immediately after surgery was without connection with the end-result.

Table 3 End results in 116 patients related to total duration of disability (TDD)

End result assessment	Per cent of patients in the group	
	"Normal" TDD	"Extended" TDD
Completely satisfied	36	10
Improved but minor complaints		
backache	39	17
leg pain	17	27
Dissatisfied	8	46
Total	100	100

DISCUSSION AND CONCLUSIONS

With a view to studying the differences in the course of events as regards disability time over a long period, the idea of "normal" and "extended" duration of disability following surgery was developed. The basic idea to separate a sample of sick individuals into two groups, the one classified as following a "normal", the other a "delayed" (in this case "extended") course of healing, is well known from the statistics of fracture healing. There is no apparent reason why this concept should not be used to characterize the course of events as regards disability time following surgery for lumbar disc prolapse. The only problem in this respect is to define the range of normality. The simplest of indirect methods for estimation of normal range, using normal probability graphs, appeared to be fully appropriate to our study.

The reliability of a diagnosis of low back disorder collected from the Health Insurance Office files can be discussed with respect to the possibility that this covers other causes of work absence. Most authors (Beals & Hickman 1972,

Westrin 1973), however, consider it improbable that sick-leave because of low back disorder covers pure malingering. The high degree of correlation between the total duration of postoperative sick leave and the patient's own assessment of the end results reflects the fact that the patient himself controls the duration of disability.

The duration of preoperative symptoms as a prognostic factor in patients operated for lumbar disc prolapse is seldom mentioned and the statements in the published reports are very controversial. Hakelius (1970) found more favourable results in patients with less than 2 months duration of sciatica, Karaharju et al (1974) noted less favourable results in these patients and Hirsch & Nachemson (1963) concluded that the end-results are not influenced by early (< 2 months) or late (> 6 months) surgery. According to Karaharju et al (1974) there is no correlation between the duration of preoperative sciatica and late symptoms, Roslund (1974) found that preoperative sciatica of more than 8 months duration is a bad prognostic factor and Jackson (1971) noted that the incidence of late low back pain is directly related to the duration of preoperative symptoms. Our own experience from this study confirms the favourable prognosis of patients operated early. If the patient has symptoms and signs enough to warrant surgery, then he should be operated on without due respect to the short duration of sciatic symptoms.

The patients in our study who had protracted total duration of disability following surgery also had some traits in common in their preoperative history. They were more often sick in general, more often on sick-leave for low back troubles, and were usually doing heavy jobs. Their signs and symptoms of sciatica are not severe enough and consequently surgery is delayed.

When one considers why surgery fails in these patients, it must be remembered that a given patient's response to pain is very much a psychological phenomenon. Beals & Hickman (1972) found a close relationship between the psychological pattern of a patient with low back injury and the time which had elapsed since injury. As the time following the injury increases the patients tend to exaggerate their physical symptoms. Wiltse & Rocchio (1975) studying patients treated with chemonucleolysis came to the same conclusion. From previously published papers and also from our own study it is not clear if these patients have had these psychological distress symptoms to begin with or if there is some cause and effect relationship provoked by the fact that the surgery was performed too late. Radiating leg pain is a symptom not a disease and the causes of the symptom may lie outside the spinal nerve root, which seems to be the case when the symptoms last for a long time.

From our study it appears that the evolution of sick leave for low back troubles during the preoperative period can be used as one of the evaluating instruments when surgical treatment in these patients is considered. At the same time the total duration of postoperative disability is one of the important criteria when the end results of lumbar disc surgery are assessed.

The results of this study also bear out the following: If the patient has prolonged leg pain symptoms but minimal objective findings, one should be very slow to resort to surgical treatment.

Every effort should be made to assess in these patients the role that emotional responses or functional overtones play in the disability presented. There is no place for explorative lumbar surgery in these patients.

ACKNOWLEDGEMENT

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REFERENCES

- Amador F & Hsu B P (1969) Indirect methods for estimating the normal range. *Amer J clin Path* 52 538-546.
- Beals R K & Hickman V W (1972) Industrial injuries of the back and extremities. *J Bone Jt Surg* 54-A 1593-1611.
- Hakelius A (1970) Prognosis in sciatica. *Acta orthop scand* Suppl 129.
- Hirsch C & Nachemson A (1963) The reliability of lumbar disk surgery. *Clin Orthop* 29 189-195.
- Jackson R K (1971) The long term effects of wide laminectomy for lumbar disc excision. *J Bone Jt Surg* 53 B 609-616.
- Karaharju E O, Alho A & Laasonen F (1974) Herniated lumbar disc: postoperative condition and correlation with preoperative and operative findings. *Ann Chir Gynaec Fenn* 63 53-56.
- Roslund J (1974) *Indications for lumbar disc surgery*. Akademisk avhandling Stockholm.
- Spangfort E V (1972) The lumbar disc herniation. *Acta orthop scand* Suppl 142.
- Westrin C G (1973) Low back sick listing. *Scand J social Med.* Suppl 7.
- Wiltse L L & Rocchio F D (1975) Preoperative psychological tests as predictors of success of chemonucleolysis in the treatment of the low back syndrome. *J Bone Jt Surg* 57 A 418-423.

SPONDYLOLISTHESIS

Treatment by Excision of the Loose Lamina and Resection of the Pedicle

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Fifty patients were treated by radical arch resection i.e. removal of the loose lamina and the fibrous tissue in and around the pseudarthrosis and resection of the caudal portion of the ventral part of the pedicle. In 17 patients an additional spinal fusion was performed. The mean observation time was 4.7 years. The forward dislocation increased by 25 per cent in the group without fusion compared with 16 per cent in the fused group. The symptoms of nerve root affection for the most part improved, but the back pain persisted in 25 patients. Fifty per cent of the patients were in full time employment at the time of the follow-up. A total of 75 per cent were improved and 25 per cent unchanged or worse.

Key words: lamina excision, pedicle resection, spondylolisthesis

Accepted 2 vii 77

The treatment of spondylolisthesis in our department, for more than 15 years, has been surgical procedures for younger patients while a more conservative approach has been the rule with older patients. During the period 1955-1970, 220 operations were performed, 80 laminectomies and 140 spinal fusions.

Studying the results of the early operations, we learned that simple laminectomy was not sufficient and that the Gill procedure (Gill et al 1955), in our hands, failed to provide relief in several cases. Alvik (1969) found, in a high percentage of cases, a special mechanism causing nerve root impingement in spondylolisthesis. The root proximal to the dislocated segment was found to be compressed to a greater or lesser extent between the pedicle of the spondylolisthetic arch and

the posterior part of the underlying corpus and disc (Figure 1).

As a consequence of this we have altered the surgical procedure. The purpose of this paper is to study the results of this revised surgical method. Laminectomy combined with resection of the pedicle, in our department called "radical arch resection".

METHOD

Radical arch resection consists of removal of the loose lamina and the fibrous tissue in and around the pseudarthrosis and in addition resection of the caudal portion of the ventral part of the pedicle (Figure 1). The patients are allowed to get out of bed 1-2 days after the operation without a corset. Active exercises are started at once.

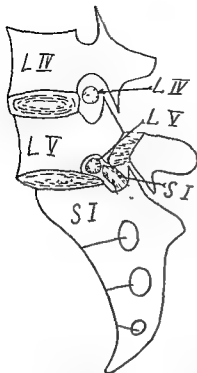


Figure 1 The part of the pedicle to be resected marked with the dotted line. The fifth lumbar root is compressed between the pedicle and the underlying bone and the disc.

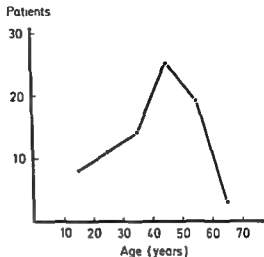


Figure 2 Age distribution

PATIENTS

A series of 80 patients have been treated with this operation during the period 1955-1970; there were 43 males and 37 females aged 12-63 years. The mean age was 39.6 years. The age distribution is shown in Figure 2. The observation time was 2-18 years with an average of 4.7 years. In 17 patients some form of spinal fusion was carried out in addition to the arch resection: 16 had posterior (intercorporeal, intertransverse or dorsal) and one anterior fusion. The fused patients were immobilised—mostly in a plaster cast—for 4 months.

In Figure 3 the anterior dislocation is graded according to Meyerding (1932). Most of the cases belonged to grades I and II (Table 1). Standard X-rays were supplemented by oblique projections in order to get an exact impression of the pseudarthrosis, which was present in all cases. The spondylolisthesis was located to L₅-S₁ in III cases, L₄-L₅ in 23 cases, L₅-S₂ in three cases, L₄-L₅ in one and L₄-L₅ and L₅-S₁ in one case. Spina bifida was found at the level of the fifth lumbar vertebra in three patients, at the

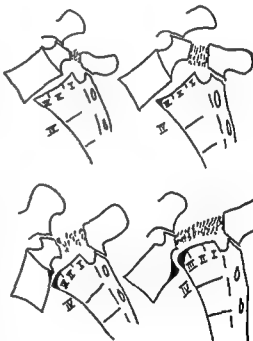


Figure 3 Grading of spondylolisthesis according to Meyerding

first sacral in five and III both the first and second sacral vertebrae in one patient. The amount of anterior dislocation of the vertebral body was recorded as a percentage of the anteroposterior diameter of the inferior surface of the displaced segment. The average slipping was 10.8 mm (21.6 per cent) ranging from zero to

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Figure 5 Grade 3-4 spondylolisthesis a) Before operation b) After radical arch excision and lateral anterior fixation which did not unite

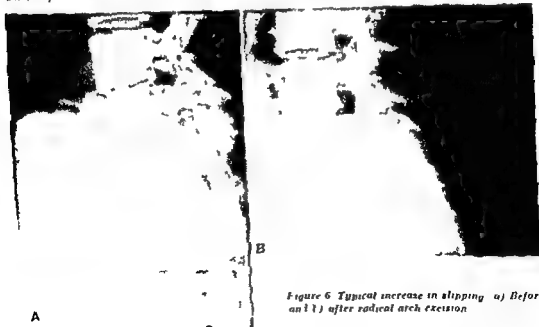


Figure 6 Typical increase in slipping a) Before and b) after radical arch excision

had less backache than the other two groups. Among the fused patients there were 10 without increased postoperative

slipping, four with moderate and three with a marked increase (> 12 mm). The last three have persistent pseudarthrosis

25 mm. In males the average slipping was 22.9 per cent and in females 28.4 per cent.

Table 1 Grading of anterior dislocation

	I	II	III	IV
Before operation	62	17	1	0
After operation	54	22	3	1

Radiulography was performed in 76 patients. Signs of nerve root affection were found in 65 cases (Figure 4). In 55 of these the radiulographic and neurologic findings correlated well. A herniated disc was found in six cases and was verified in five cases at operation. One additional prolapse, not demonstrated radiulographically, was found at operation.

Complications: reoperation and additional spinal fusions

In the group of 63 patients without fusion there were no immediate postoperative complications. Three patients, however, were reoperated and neurolysis performed because of persistent root symptoms. Only one improved. An other four patients had additional anterior transperitoneal fusion because of a considerable increase in anterior dislocation following the initial operation. One of these did not heal (Figure 5). In one case a third operation—neurolysis—was performed because of persistent radicular and back pain but no improvement resulted. This patient also developed a ventral hernia after the fusion operation. Additional fusion was done in another three patients because of persistent severe back pain: one intertransverse, one combined dorsal/intertransverse and one dorsal. The latter patient developed a deep wound infection with a fistula and had to be reoperated because of non union.

In the combined radical/fusion group of 17 patients two developed superficial infection. Non union occurred in two of the six intercorporal fixations. Intertransverse fusion was done in one of them. Of the three dorsal fixations, two did not heal and were reoperated twice. One of them has a persistent pseudarthrosis. One patient with anterior fusion initially was reoperated and intertransverse fixation performed because of persistent back pain.

RESULTS

Postoperative slipping. Following radical resection without fusion the anterior dis-

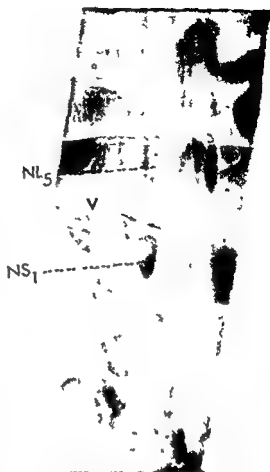


Figure 4 Radiulogram. The fifth lumbar root is disrupted at the pseudarthrosis level marked with arrows. Note increased interval between pedicle and root.

Table 2 Pre- and postoperative slipping for patients having radical arch excision without fusion

Age (years)	No. of patients	Dislocation pre and postop (mm)	Dislocation increase (mm)	% increase
< 25	11	13.9-17	3.1	22.3
25-40	20	11.6-15.1	3.5	30.2
> 40	35	10-12.1	2.1	21
Total	66	11-13.7	2.7	25

location increased from 11 mm to 13.7 mm (Figure 6). The slipping was most marked in the middle age group (25-40 years) (Table 2). Surprisingly this group



Figure 5 Grade 3-4 spondylolisthesis a) Before operation b) After radical arch excision and lateral anterior fixation which did not unite

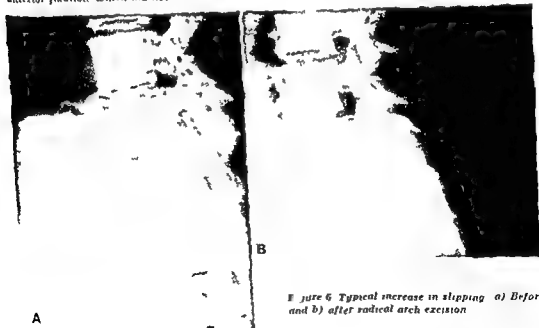


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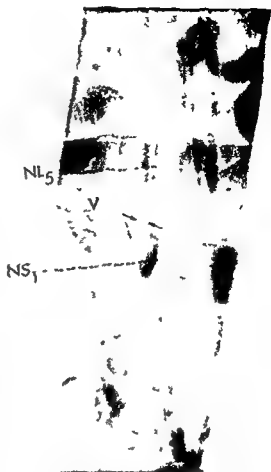


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25-40	20	11.6-15.1	1.5	30.2
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Total	63	11-13.7	2.7	25

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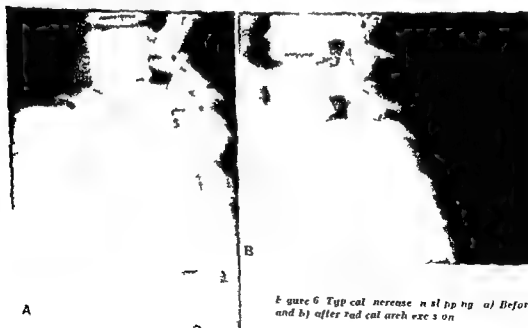


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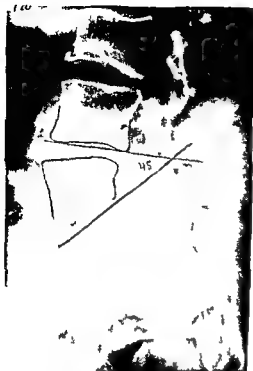


Figure 7 Postoperative rolling. The angle between the upper sacrum and the fourth vertebra has increased.

In some cases rolling was observed on X-ray examination, i.e. an increased angle between the sacrum and the vertebra above the slipping vertebra (Figure 7).

Nerve root affection. The signs of root affection were markedly improved. The radicular pain, which was present in all cases before operation, was improved in 63 (78.8 per cent). Objective signs present in 45 patients preoperatively were improved at follow up in 38 (Table 3).

Table 3 Nerve root symptoms before and after operation

		Radicular pains	Objective root signs
Before operation		80	45
After operation	No symptoms	45	30
	Improved	18	8
	Unchanged	12	6
	Worse	5	1

Local back pain. In 49 patients (61.3 per cent) the back pain was considerably improved. It was unchanged in 22 and worse in six patients. Three patients had no pain before or after operation. One patient without back pain before opera-

Patients

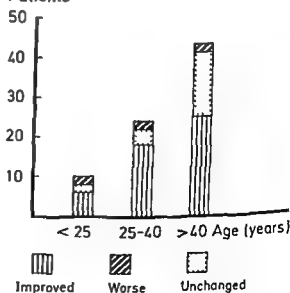


Figure 8 Back pain related to age. See text.

tion complained of pain at the follow up. The middle age group seemed to be the most pain free (Figure 8).

Working capacity As shown in Table 4 the working capacity was greatly improved. The number of patients in employment was doubled after operation.

Table 4 Working capacity

	Before oper- ation	After oper- ation
Incapable of working	46	20
Partial working capacity	14	20
Full working capacity	70	40

Overall end results were graded as follows:

Excellent	No pain or mild occasional pain. Able to carry out all activities.
Fair	Improved with moderate pain in the back and/or extremities. Working capacity reduced to some degree.
Poor	Persistent or increased pain in the back or lower extremities. Incapable of working.

As demonstrated in Table 5 half of the patients obtained a very satisfactory result. 75 per cent were improved and 70 per cent are classified as failures. With out fusion 30 per cent were failures.

Table 5 Overall results

	Radical arch excision		Completed operation	
	No of patients	%	No of patients	%
Excellent	31	49	9	53
Fair	13	21	7	41
Poor	19	30	1	6
Total	63	100	17	100

DISCUSSION AND CONCLUSION

Bosworth et al (1955) and Marmor & Bechtol (1961) thought that removal of the loose lamina might lead to instability with increasing anterior dislocation. Gill et al (1955) did not share this opinion. In agreement with Friberg (1939) Gill et al (1955) and Turner & Bianco (1971) we have not found any correlation between the grade of slipping and back pain.

In addition to the radical arch excision we now invariably perform intervertebral fusion in patients below 50. Since 1969 we have used the intertransversal method which is simple and has proved for us to be the most reliable. After radical arch excision the symptoms of nerve root affection as a rule disappear or improve but the back pain often persists. We believe that the backache is largely due to small movements in the dislocated segment. Residual back pain after arch excision is therefore logically treated by secondary fusion.

Compared with Gill's series our number of good results seems to be rather modest. But they correspond well with the results of Cedell (1961) and Cedell & Wiberg (1970) who recorded distinct improvement in about 70 per cent of their series. The evaluation of the results however is not always commensurable. We believe that the present attitude towards treatment of spondylolisthesis is not the final one. It may be that the selection of cases for surgical treatment should be more restrictive. We feel that a few of the patients in the failure group would have been dissatisfied irrespective of treatment. These patients are particularly liable to be victims of multisurgery.

REFERENCES

- ÅL I (1969) Spondylolisthesis. *Tidsskrift for Læger* 89: 1344-1346.
Bosworth H M, Felding W., Demarest L. &

- Bonaquist, M (1955) Spondylolisthesis A critical review of a consecutive series of cases treated by arthrodesis *J Bone Jt Surg* 37 A, 767-786
- Cedell, C A (1961) On the effect of laminectomy on back pain in spondylolisthesis *Acta orthop scand* 31, 130
- Cedell C A & Wihberg G (1970) Long term results of laminectomy in spondylolisthesis *Acta orthop scand* 40 773-776
- Eriberg S (1939) Studies of spondylolisthesis *Acta chir scand* 82, Suppl 55
- Gill G G Manning, J C & White, H L (1955) Surgical treatment of spondylolisthesis without spine fusion *J Bone Jt Surg* 37 A 493-520
- Gill, G G & White, H L (1965) Surgical treatment of spondylolisthesis without spine fusion *Acta orthop scand*, Suppl 85, 5-99
- Marmor, L & Bechtol, C D (1961) Complete slip following the Gill procedure A case report *J Bone Jt Surg* 43 A, 1068-1069
- Meyerding W W (1932) Spondylolisthesis *Surg Gynec Obstet* 54 371-377
- Turner, R H & Bianco Jr, A J (1971) Spondylolysis and spondylolisthesis in children and teenagers *J Bone Jt Surg* 53 A 1298-1306

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THE SURGICAL TECHNIQUE FOR HINDQUARTER AMPUTATION

A Report of 19 Cases

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The surgical technique for hindquarter amputation is described in a step by step manner. Since 1955 we have performed 19 such operations for eradication of malignant bone and soft tissue tumors in the pelvic, hip and upper thigh regions. Three hindquarter amputations were performed for local recurrence following initial wide excision. The overall 5 year survival rate for our 19 patients was 42.1 per cent. Malignant soft tissue tumors appear to have a much better 5-year survival rate than malignant bone tumors (60 per cent vs. 22.2 per cent). We feel that surgery is still the treatment of choice. However, in the presence of proper indications, chemotherapy and radiotherapy should be added to surgery in order to prolong survival time and save lives.

Key words: hindquarter amputation, hemipelvectomy.

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MATERIAL

From 1955 to 1975 331,471 inpatient operations were performed at Henry Ford Hospital. However, only 19 hindquarter amputations were done during the same period. This means that hindquarter amputation represented only one

- Bonaquist, M (1955) Spondylolisthesis. A critical review of a consecutive series of cases treated by arthrodesis *J Bone Jt Surg* 37 A, 767-786
- Cedell, C A (1961) On the effect of laminectomy on back pain in spondylolisthesis *Acta orthop scand* 31, 130
- Cedell, C A & Wiberg G (1970) Long term results of laminectomy in spondylolisthesis *Acta orthop scand* 40 773-776
- Friberg S (1939) *Studies of spondylolisthesis* *Acta chir scand* 82, Suppl 55
- Gill, G G, Manning, J C & White, H L (1955) Surgical treatment of spondylolisthesis without spine fusion *J Bone Jt Surg* 37 A 493-520
- Gill, G G & White, H L (1965) Surgical treatment of spondylolisthesis without spine fusion *Acta orthop scand*, Suppl 85 5-99
- Marmor, L & Bechtol, C D (1961) Complete slip following the Gill procedure. A case report *J Bone Jt Surg* 43 A, 1069-1069
- Meyerding M W (1932) Spondylolisthesis *Surg Gynec Obstet* 54, 371-377
- Turner, R H & Blanco Jr, A J (1971) Spondylolysis and spondylolisthesis in children and teen agers *J Bone Jt Surg* 53 A 1298-1306

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THE SURGICAL TECHNIQUE FOR HINDQUARTER AMPUTATION

A Report of 19 Cases

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The surgical technique for hindquarter amputation is described in a step-by-step manner. Since 1935 we have performed 19 such operations for eradication of malignant bone and soft tissue tumors in the pelvic, hip and upper thigh regions. Three hindquarter amputations were performed for local recurrence following initial wide excision. The overall 5-year survival rate for our 19 patients was 42.1 per cent. Malignant soft tissue tumors appear to have a much better 5-year survival rate than malignant bone tumors (60 per cent vs. 22.2 per cent). We feel that surgery is still the treatment of choice. However, in the presence of proper indications, chemotherapy and radiotherapy should be added to surgery in order to prolong survival time and save lives.

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MATERIAL

From 1935 to 1975, 331,471 inpatient operations were performed at Henry Ford Hospital. However, only 19 hindquarter amputations were done during the same period. This means that hindquarter amputation represented only one

per approximately 17 000 operations or in terms of time one per year

The indications for our 19 hindquarter amputations are summarized in Table 1

Table 1

Disease	Number of patients
Malignant primary bone tumors	
Osteogenic sarcoma	4
Chondrosarcoma	4
Ewing's sarcoma	1
Malignant soft tissue tumors	
Rhabdomyosarcoma	4
Fibrosarcoma	3
Mesenchymoma	2
Extraosseous osteogenic sarcoma	1

There were 11 males and 8 females. Sixteen of them were white and three black. Their age distribution is shown in Table 2

Table 2

Decade	Number of patients
0-9	0
10-19	4
20-29	2
30-39	3
40-49	2
50-59	2
60-69	6

METHODS

Primary treatments in our 19 patients are listed in Table 3

Table 3

Primary treatment	Hindquarter amputation	Wide local resection	Radiotherapy plus hindquarter amputation
Number of patients	15	3	1

With the exception of the one case of Ewing's sarcoma, radiotherapy and chemotherapy were

reserved for recurrence of tumor and metastases. Only one patient underwent pulmonary lobectomy for metastases and he died 1½ years postoperatively from widespread metastases. No prophylactic chemotherapy was used in this series.

SURGICAL TECHNIQUE

Prior to the amputation, insertion of a Foley catheter, suturing of the anus and administration of prophylactic intravenous antibiotic are routinely carried out. The patient is placed in a lateral position and the affected leg is held in 45° of abduction.

The amputation is performed in five steps

1. Step one, the skin incision (Figure 1), begins from the superior aspect of the sacroiliac joint, going along the iliac crest to the anterior superior iliac spine and then following the inguinal ligament to the pubic tubercle where the line becomes bifurcated: one to the pubic

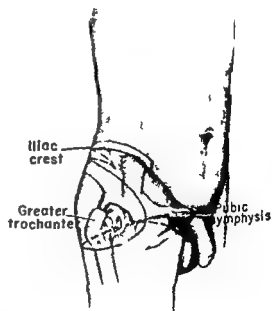


Figure 1 The skin incision

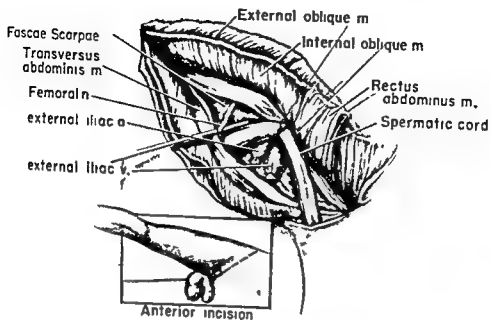


Figure 2 The anterior incision and resection

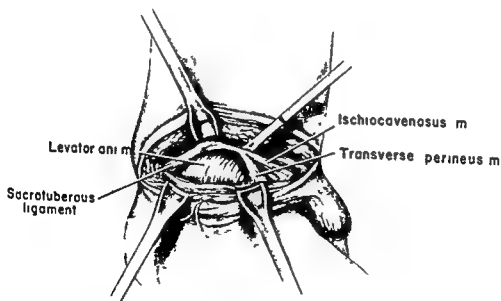


Figure 3 The perineal resection

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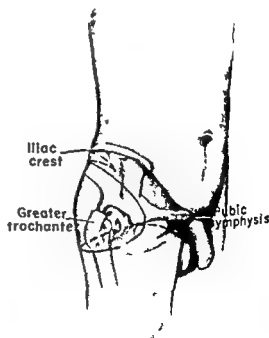
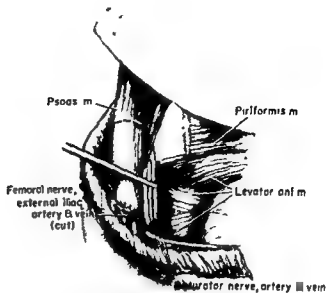


Figure 1 The skin incision

Figure 5 The intrapelvic resection



(Figures 4 and 5), is performed in the following order

a Detach the remaining abdominal muscles, the quadratus lumborum and the erector spinae muscles from the ilium

b Divide the gluteus maximus slightly above its insertion at linea aspera and retract the whole muscle together with its overlying skin and subcutaneous

tissue as one flap upward and medialward

c Divide the piriformis muscle and the sciatic nerve

d Disarticulate the sacroiliac joint with a gigli saw

e Cut the sacrotuberous and sacrospinous ligaments

f Through the anterior incision, ligate and divide the obturator artery and vein

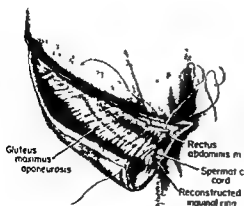


Figure 6 The reconstruction of inguinal ring and canal and skin closure

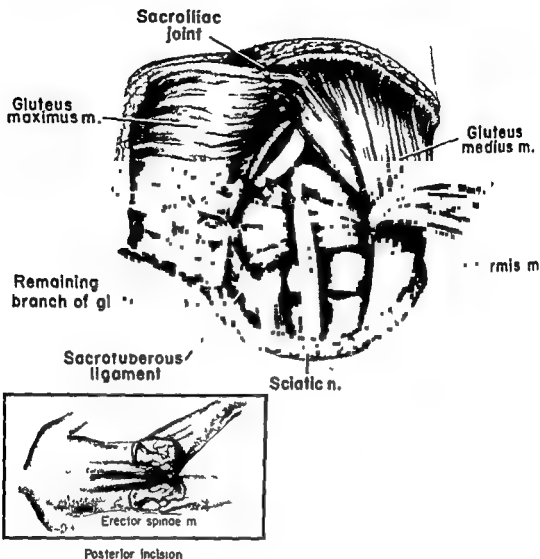


Figure 4 The posterior resection

symphysis, and the other along the perineal crease to the beginning of the gluteal fold. The incision then travels the entire length of the gluteal fold to the greater trochanter from which the line is curved upward and medialward, slightly below the iliac crest, to the starting point.

2 Step two, the anterior approach (Figure 2), is done in the following manner:

a Detach the abdominal muscles, the inguinal ligament and the rectus abdominis muscle from their respective iliac and pubic attachments.

b By retracting the spermatic cord

and peritoneum upward and medialward ligate and divide the external iliac artery and vein and then cut the femoral nerve at the same level.

c By retracting the bladder into the pelvis, the pubic symphysis is distracted by means of complete division of its ligaments and fibrocartilage.

3 Step three, the perineal approach (Figure 3), is accomplished by detaching the ischiocavernosus, the transverse perineal and the origin of the upper levator ani muscles from the pubic bone in a subperiosteal manner.

4 Step four, the posterior approach

Table 7

Author	Year	Number of patients	3 year survival rate (percent)
Gordon Taylor & Munroe	1952	50	20
Higinbotham & Coley	1956	30	40
Lewis & Bickel	1957	50	50
Bailey & Steven	1961	16	20
Pack & Miller	1964	53	20.6
Marove et al	1972	65	51

However in order to improve our patients long term survival rate, adjuvant chemotherapy is now routinely employed in treating certain malignant tumors, such as osteogenic sarcoma Ewing's sarcoma embryonal rhabdomyosarcoma etc. Furthermore in addition to surgery, radiotherapy and chemotherapy, we believe that immunotherapy will be added to our armamentarium when its effectiveness has been unequivocally proven.

ACKNOWLEDGMENT

We wish to thank Mr Jay Kimpstein for his superb drawings.

REFERENCES

- Allred A J & Nisbet A W (1964) Hydatid disease of bone in Australia *J Bone Jt Surg* 46 B 260-267
- Bailey R W & Steven D B (1961) Radical exarticulation of the extremities for the curative and palliative treatment of malignant neoplasms *J Bone Jt Surg* 43 A 821
- Banke S W & Coleman S (1956) Hemipelvectomy: surgical technique *J Bone Jt Surg* 38 A 1147-1155
- Beck A H & Bickel W H (1948) Interim (intraabdominal) amputations: Report of twelve cases *J Bone Jt Surg* 30 A 201-209
- Gordon Taylor G (1950) A further review of the interinnominal abdominal operation: Eleven personal cases *Brit J Surg* 27 643-650
- Gordon Taylor G & Munroe R (1952) Tech-

- nique and management of hindquarter amputation *Brit J Surg* 39 536-541
- Gordon Taylor G & Wiles P (1935) Interinnominal abdominal (hindquarter) amputation *Brit J Surg* 22 671-695
- Gordon Taylor G Wiles P & Warwick W J (1952) The interinnominal abdominal operation: Observation on a series of fifty cases *J Bone Jt Surg* 34 B 14-21
- Higinbotham N L & Coley B L (1956) Hemipelvectomy: Experience in a series of thirty nine cases *Cancer (Philad)* 9 1233-1238
- Johansson H & Olerud E (1971) Traumatic hemipelvectomy in a ten year-old boy *J Bone Jt Surg* 53 A 170-172
- King D & Steelquist J (1943) Transiliac amputation *J Bone Jt Surg* 25 351-367
- Lee C W & Alt L P (1953) Hemipelvectomy and hip disarticulation for malignant tumors of the pelvis and lower extremity *Ann Surg* 137 704
- Lewis R C & Bickel W H (1957) Hemipelvectomy for malignant disease *J Amer med Ass* 165 8-12
- Marove R C Mike V Hutter R V P Huvos A G Shoji H Miller T R & Kosloff R (1972) Chondrosarcoma of pelvis and upper end of the femur *J Bone Jt Surg* 54-A 561-572
- McLean F M (1962) Avulsion of the hind quarter *J Bone Jt Surg* 44 B 384-385
- McPherson J H T (1960) Traumatic hind quarter amputation *J med Ass Ga* 49 494-495
- Pack G T (1956) Major exarticulation for malignant neoplasms of the extremities: Interscapulo thoracic amputation hip joint disarticulation and femoro abdominal amputation: A report of end results in 228 cases *J Bone Jt Surg* 38 A 249-262
- Pack G T & Ehrlich H E (1946) Exarticulation of the lower extremities for malignant tumors: Hip joint disarticulation (with and without deep iliac dissection) and sacro iliac disarticulation (hemipelvectomy) *Ann Surg* 124 1-27
- Pack G T Ehrlich H E & Gentil F D (1947) Radical amputations of extremities in the treatment of cancer *Surg Gynec Obstet* 84 1105-1116
- Pack G T & Miller T R (1964) Exarticulation of the innominate bone and corresponding lower extremity (hemipelvectomy) for primary and metastatic cancer: A report of one hundred and one cases with analysis of the end results *J Bone Jt Surg* 46-A 91-95
- Phelan J T, Grace J T, Jr & Moore G E (1964) Hemipelvectomy for the management of soft tissue tumors of the lower extremities *Amer J Surg* 107 604-608

Table 4

Number of patients	Nature of disease	Site	Results
1	Chondrosarcoma	Proximal femur	All had local recurrence which required subsequent hindquarter amputation
1	Fibrosarcoma	Soft tissue of thigh	
1	Malignant mesenchymoma	Soft tissue of thigh	

Table 5

Duration	1 year		2 years		5 years and more	
	Dead	Living	Dead	Living	Dead	Living
Number of patients	5	14	9	10	11	8
Per cent	26.3	73.7	47.4	52.6	57.9	42.1

and cut the obturator nerve and the psoas muscle

■ Completely detach the levator ani muscle from the pubic bone to free the entire hindquarter

5 Step five, the closure (Figure 6), is done in the following manner

a Reconstruct an external inguinal ring for the passage of spermatic cord by selectively suturing the lower medial corner of the gluteus maximus aponeurosis to the rectus abdominis and the medial portion of the abdominal muscles

b The remaining gluteus maximus flap is sutured to the lateral portion of the abdominal muscles and the quadratus lumborum and psoas muscles

c After the insertion of soft rubber drains or plastic suction tubings, the skin and subcutaneous tissues are closed in the usual manner

RESULTS

Recurrence The incidence of recurrence of tumors following local resection is summarized in Table 4

Survival rates The overall short-term and long-term survival rates of our 10 patients are shown in Table 5

The comparison of the 5-year survival rates between malignant soft tissue tumors and malignant bone tumors is presented in Table 6

Table 6

Disease	Number of patients		5 year survival rate
	Dead	Living	
Malignant soft tissue tumors	4	6	60%
Malignant bone tumors	7	3	22.2%

DISCUSSION

Although hindquarter amputation is an extremely mutilating operation, it is still the only reliable way of completely eradicating malignant tumors from the buttock, hip and upper thigh region, provided that metastases have not yet taken place. Our experience of a 42 per cent overall 5-year survival rate compares favorably with the published series in the medical literature which are shown in Table 7

A STUDY OF RADIOGRAPHIC VARIATIONS OF THE HIP JOINT

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Philadelphia, Pennsylvania, 19104

Anteroposterior radiographs of the pelvis were studied in 920 patients free of hip joint diseases. The average joint space was between 3 and 4 mm in width. Narrowing of the superior joint space was seen in 13 percent of the hips and may represent the earliest finding in osteoarthritis. It was noted as early as the second and third decade in some patients. Other changes noted were narrowing of the lateral joint space, uniform narrowing of the space, an irregular joint space and tilting of the femoral head on the neck.

Key words: blurred eyebrow, CE angle, femoral head ratio, joint space narrowing.

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In most instances the etiology of osteoarthritis cannot be related to a specific injury or congenital malformation. Congenital dysplasia, coxa vara, Perthes' disease, overt slipped epiphysis and protrusio acetabuli are some conditions recognized as precursors of osteoarthritis. In order to cast some light on this problem a study was made of hip radiographs to determine what alterations exist in hips considered to be normal.

In an effort to determine the earliest roentgenographic abnormalities which may lead to manifest osteoarthritis of the hip, the anteroposterior views of urograms in 920 patients were studied.

Urograms were employed as they were the only available source of a large number of pelvic films showing the hip joints and because there is no known direct correlation between urinary tract diseases and degenerative joint disease of the hip joint.

MATERIALS AND METHOD

The 920 urograms were selected at random from the radiographic files of the University of Pennsylvania. Any film with established changes of osteoarthritis such as total joint narrowing, sclerosis of the subchondral bone, osteophytes, cysts or irregular surfaces was discarded. Any film in which a true anteroposterior projection was not made was also not used.

The hips were reviewed with particular attention to the interspace distance between the head and the acetabulum and for changes in the acetabular and femoral surfaces. Age, sex and race were known and the CE angle and interspace distance were measured.

The joint space distance was measured on a vertical line through the geometric center of the head. The narrowest joint space distance was also measured on a line passing through the geometric center (Figure 1). The CE angle was measured as described by Wiberg (1939).

Displacement of the femoral head on the neck was measured according to Murray (1965) using the "femoral head ratio". First a line was drawn from the most lateral part of the greater trochanter to the most medial part of the lesser trochanter and the center was determined. The

- Sorondo, J P & Ferre, R L (1948) Amputation interilioabdominal *An Ortop Traum* **1** 143
- Sugarbaker, E D & Ackerman I V (1949) Disarticulation of the innominate bone for malignant tumors of the pelvic parietes and upper thigh *Surg Gynec Obstet* **81** 36-52
- Wade, I V & Macksood, W A (1965) Traumatic hemipelvectomy. A report of two cases with rectal involvement *J Trauma* **5** 554-562
- Wise, R A (1949) Hemipelvectomy for malignant tumors of the bony pelvis and upper part of the thigh *Arch Surg* **58** 867-874

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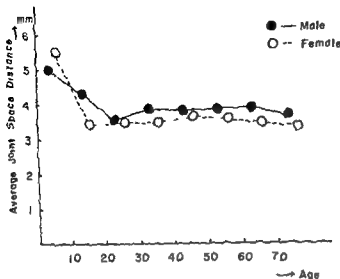


Figure 3 Joint space distance at different ages

incidence decreased significantly in the eighth decade. The average for females was 10.7 percent. The interesting features of this group were (1) This finding was first seen in the younger patients in the second or third decade and (2) in the older patients the finding was not associated with radiologic osteoarthritis (Table 1 and Figure 4).

2) Lateral narrowed joint space

The lateral joint space is between the lateral border of the acetabulum and

head. Narrowing of the lateral joint space was seen in 24 hips (13 percent). The narrowing was always found at the most lateral part of the joint, which is not in the major weight-bearing area. Changes were first seen in the fourth decade and were present in each subsequent decade but did not increase significantly (Table 2). This finding was more common in females (Figure 5).

3) Uniformly narrowed joint space

The joint space was less than 2 mm in

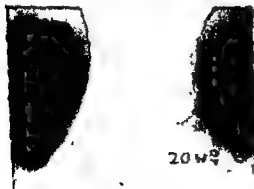


Figure 4 Superior narrow joint space on the left 20 year old white female had left superior narrow joint space CE angle 23°. Over the superior head joint space was 2 mm



Figure 5 Lateral narrowed joint space on the left 63 year-old white male had left lateral narrowed joint space CE angle 29°. Lateral interspace was 1 mm

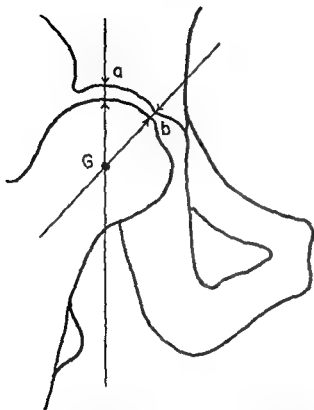


Figure 1 Measurement of joint space distance
a Joint space distance on the vertical line that passes the geometric center of the femoral head
b Joint space distance at the narrowest part
G Geometric center of the femoral head

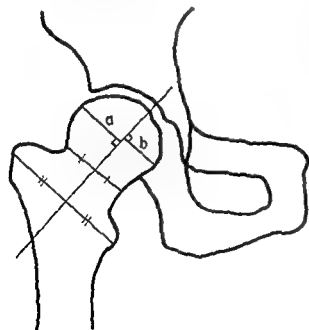


Figure 2 Femoral head ratio
 $\frac{b}{a} = \text{Femoral head ratio}$

center point at the narrowest part of the neck was also established and a line was then drawn connecting these two points and extending into the proximal femoral head. The maximum distance to each side of the head is measured from this line, the most lateral distance expressed by 'a' and the most medial distance by 'b'. 'a' is called the femoral head ratio (Figure 2).

RESULTS

The average joint space distance measured on the vertical line "a" as in Figure 1 was 3.8 mm in males (standard deviation 0.9 mm); in females the average was 3.5 mm (standard deviation 0.8 mm). A joint space of 2 mm or less was regarded as abnormal. Individuals younger than 10 years showed a wider joint space than older individuals but few of our patients were in this age group. The average joint space did not significantly diminish with age (Figure 3).

The variations noted were as follows:

1) A superior narrowed joint space

This was the joint space measured at the narrowest part between the superior surface of the head and the acetabulum and corresponds to the oblique line "b" drawn through the geometric center of the head as in Figure 1. This was the largest group deviating from the normal or average radiograph. 236 of the 1840 hips were in this group (12.8 percent). The joint space was narrowest where the most prominent weight-bearing trabeculae passing from the head to the pelvis were found. This point is usually located in the weight-bearing area at the superior part of the dome of the femoral head. In males this change was first noted in the second decade. The incidence increased gradually and reached a maximum in the fourth decade. It decreased in the fifth and sixth decades, and its incidence again increased in the seventh and eighth decades. The average for males was 14.9 percent.

In females this narrowing was most common in the seventh decade and the



Figure 6 Uniformly narrowed joint space 20 year old white male had bilateral uniformly narrowed joint space CF angle right 23° left 31° Joint space distance right 2 mm left 2 mm Left hip is shown



Figure 7 Diffuse lateral acetabular edge (blurred eyebrow) 47 year old white male had hips with blurred eyebrow CE angle right 77° left 31° Joint space distance right 5 mm and left 4 mm Left hip is shown

three measurements along lines drawn through the geometric center on these films There were three male and four female hips in this group (Figure 6)

4) Thickened and diffuse lateral acetabular edge (blurred eyebrow)

These films showed an interesting loss of clarity of the lateral acetabular edge which was thickened in the para articular zone The thickened part was likened to an eyebrow covering the lateral femoral head The change was distributed rather uniformly in each decade being highest in the seventh in both sexes The total number of hips with this "blurred eyebrow" was 34 (18 percent) 21 in males and 13 in females (Table 1 and Figure 7)

5) Changes in the shape of the femoral head

Radiographs in this group revealed femoral heads which were asymmetrical in the anteroposterior plane This group differed from the superior narrowed the lateral narrowed or uniformly narrowed groups in that there were abrupt alterations of the joint space secondary to ir

regularity of the femoral head surface Five such hips were seen (03 percent) Three were in males two in females (Figure 8)

6) Displacement of the femoral head

When a femoral head deviated from the neck axis it was always in an inferior direction In each of these hips the femoral head ratio was greater than 1.35 indicating an inferior displacement Sev



Figure 8 Change in the shape of the femoral head 70 year old female with b lateral femoral head irregularity Interspace was 4 mm in both hips and CF angle was 36° in both hips Right hip is shown

Table 1 Superior narrowed joint space

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	2	6	20	16	30	44	23	141
	Hips in each age group		2	56	88	98	138	212	232	122	948
	%		0	16	6.8	20.4	11.6	14.2	19.0	18.9	14.9
Female	Narrowed		0	0	7	8	16	14	38	12	95
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	5.3	7.0	9.3	8.2	26.0	11.8	10.7

Table 2 Lateral narrowed joint space

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	0	0	2	0	0	2	2	6
	Hips in each age group		2	56	88	98	138	212	212	122	948
	%		0	0	0	2.0	0	0	0.9	1.6	0.6
Female	Narrowed		0	0	0	2	8	3	5	0	18
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	0	1.8	4.7	1.8	3.4	0	2.0

Table 3 Thickened and diffuse lateral acetabular edge (flurred eyel row)

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	2	0	2	5	2	0	1	21
	Hips in each age group		2	56	88	98	138	212	232	122	948
	%		0	1.6	0	2.0	3.6	0.9	0.9	0.8	2.2
Female	Narrowed		0	0	1	2	0	4	4	2	13
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	0.8	1.8	0	2.4	2.7	2.0	1.5



Figure 6 Uniformly narrowed joint space 20 year old white male had bilateral uniformly narrow joint space CE angle right 24° left 31° Joint space distance right 2 mm left 2 mm Left hip is shown



Figure 7 Diffuse lateral acetabular edge (blurred eyebrow) 57 year old white male had hips with blurred eyebrow CF angle right 27° left 31° Joint space distance right 3 mm and left 4 mm Left hip is shown

three measurements along lines drawn through the geometric center on these films. There were three male and four female hips in this group (Figure 6)

4) Thickened and diffuse lateral acetabular edge (blurred eyebrow)

These films showed an interesting loss of clarity of the lateral acetabular edge which was thickened in the para articular zone. The thickened part was likened to an eyebrow covering the lateral femoral head. The change was distributed rather uniformly in each decade being highest in the seventh in both sexes. The total number of hips with this blurred eyebrow was 34 (18 percent) 21 in males and 13 in females (Table II and Figure 7)

5) Changes in the shape of the femoral head

Radiographs in this group revealed femoral heads which were asymmetrical in the anteroposterior plane. This group differed from the superior narrowed the lateral narrowed or uniformly narrowed groups in that there were abrupt alterations of the joint space secondary to ir-

regularity of the femoral head surface. Five such hips were seen (0.3 percent). Three were in males, two in females (Figure 8)

6) Displacement of the femoral head

When a femoral head deviated from the neck axis, it was always in an inferior direction. In each of these hips the femoral head ratio was greater than 1.35 indicating an inferior displacement. Sev-



Figure 8 Change in the shape of the femoral head 70 year old female with bilateral femoral head irregularity Interspace was 4 mm in both hips and CF angle was 36° in both hips Right hip is shown

Table 1 Superior narrowed joint space

	Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed	0	2	6	20	16	30	44	23	141
	Hips in each age group	2	56	88	98	138	212	232	122	949
	%	0	3.6	6.8	20.4	11.6	14.2	19.0	18.9	14.9
Female	Narrowed	0	0	7	8	16	14	38	12	91
	Hips in each age group	8	48	132	114	172	170	146	102	892
	%	0	0	5.3	7.0	9.3	8.2	26.0	11.8	10.7

Table 2 Lateral narrowed joint space

	Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed	0	0	0	2	0	0	2	2	6
	Hips in each age group	2	56	88	98	138	212	232	122	948
	%	0	0	0	2.0	0	0	0.9	1.6	0.6
Female	Narrowed	0	0	0	2	8	3	5	0	18
	Hips in each age group	8	48	132	114	172	170	146	102	892
	%	0	0	0	1.8	4.7	1.8	3.4	0	2.0

Table 3 Thickened and diffuse lateral acetabular edge (blurred eyebrow)

	Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed	0	2	0	2	5	2	9	1	21
	Hips in each age group	2	56	88	98	138	212	232	122	948
	%	0	3.6	0	2.0	3.6	0.9	3.9	0.8	2.2
Female	Narrowed	0	0	1	2	0	4	4	2	13
	Hips in each age group	8	48	132	114	172	170	146	102	892
	%	0	0	0.8	1.8	0	2.4	2.7	2.0	1.5



Figure 6 Uniformly narrowed joint space 20 year old white male had bilateral uniformly narrowed joint space CF angle right 25° left 31° Joint space distance right 2 mm left 4 mm Left hip is shown



Figure 7 Diffuse lateral acetabular edge (blurred eyebrow) 57 year old white male had hips with blurred eyebrow CF angle right 27° left 33° Joint space distance right 5 mm and left 4 mm Left hip is shown

three measurements along lines drawn through the geometric center on these films. There were three male and four female hips in this group (Figure 6)

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Radiographs in this group revealed femoral heads which were asymmetrical in the anteroposterior plane. This group differed from the superior narrowed, the lateral narrowed or uniformly narrowed groups in that there were abrupt alterations of the joint space secondary to ir-



Figure 8 Change in the shape of the femoral head 60-year-old female with bilateral femoral head irregularity. Interspace was 4 mm in both hips and CE angle was 36° in both hips. Right hip is shown

Table 1 Superior narrowed joint space

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	2	6	20	16	30	44	23	141
	Hips in each age group		2	56	88	98	178	212	232	122	948
	%		0	3.6	6.8	20.4	11.6	14.2	19.0	18.9	14.9
Female	Narrowed		0	0	7	8	16	14	38	12	95
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	5.3	7.0	9.3	8.2	26.0	11.8	10.7

Table 2 Lateral narrowed joint space

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	0	0	2	0	0	2	2	6
	Hips in each age group		2	56	88	98	179	212	232	122	948
	%		0	0	0	2.0	0	0	0.9	1.6	0.6
Female	Narrowed		0	0	0	2	8	3	5	0	18
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	0	1.8	4.7	1.8	3.4	0	2.0

Table 3 Thickened and diffuse lateral acetabular edge (blurred eyebrow)

		Age	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-89	Total
Male	Narrowed		0	2	0	2	5	2	0	1	21
	Hips in each age group		2	56	88	98	138	212	232	122	948
	%		0	3.6	0	2.0	3.6	0.9	3.9	0.8	2.2
Female	Narrowed		0	0	1	2	0	4	4	2	13
	Hips in each age group		8	48	132	114	172	170	146	102	892
	%		0	0	0.8	1.8	0	2.4	2.7	2.0	1.5

Table 5 Incidence of bilateral

		Superior narrowed	Lateral narrowed	Uniformly narrowed	Acetabular change	Irregular fem head	Head tilt
	No of bilat pt	59	1	1	6	1	1
Male	No of pt	82	1	2	15	2	6
	%	72.0	20	50	40	50	16.7
	No of bilat pt	46	3	1	4	1	0
Female	No of pt	49	15	3	9	1	0
	%	93.9	20	33.3	44.4	100	0

second and third decades. If a subtle narrowing is a harbinger of joint disease in later life, it should be possible to identify the individuals who may develop this condition at an early age. The narrowed area coincides with the weight-bearing area where prominent trabeculae straddle the joint.

The shifting of the femoral head relative to the neck has been described by Murray (1965) as a tilt deformity and he felt this could be the result of a minimally slipped capital epiphysis. Five hips showed such a deformity which may well lead to an osteoarthritis.

The blurred eyebrow was seen in

two percent of the hips. The pathology of this condition has not been described to our knowledge. It would appear to be a very early stage of subchondral sclerosis perhaps related to alteration of weight bearing stresses with a lateral shift of the weight bearing axis.

REFERENCES

- Murray, H. O. (1965) The aetiology of primary osteoarthritis of the hip. *Brit J Radiol* 38 810-824.
 Wiberg G. (1939) Studies on dysplastic acetabular and congenital subluxation of the hip joint. *Acta chir scand* 85 Suppl. 58.

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Figure 9 Displacement of femoral head on the neck 58 year old white male both femoral heads deviate inferomedially CE angle right 27°, left 25° FHR right $\frac{34}{25} = 1.36$ left $\frac{34}{25} = 1.42$ Left hip is shown (FHR of more than 1.35 shows tendency for inferomedial displacement of the femoral head)

on hips showed a change of this type (0.4 percent). All were in males (Figure 9)

In 141 male hips in which none of the above abnormalities were noted the average CE angle was 32° (standard deviation 6.6°). The minimum was 15° and the maximum 47°. In 95 female hips showing no abnormalities, the CE angle was 35° (standard deviation 7.4°). The minimum was 19° and the maximum 56°. In both male and female hips showing a superior narrowed joint space no significant change in CE angle was noted. No correlation could be made between the CE angle and the other abnormalities studied (Table 4).

DISCUSSION

Degenerative joint disease of the hip is associated with a narrow, irregular joint space in the advanced state. In this study 85 percent of the hip joints showed a uniform joint space without local narrowing. Superior joint space narrowing occurred in 13 percent of the hips (in 82 percent of these hips, it was bilateral). Bilaterality of the other hip variations was not common (Table 5). This narrowing was more common in the older age groups and may be an early stage of degenerative joint disease. If this type of narrowing is a precursor of an osteoarthritis, it may develop at an early age in some individuals as it was seen in the

Table 4 CE angle versus each group of variations noted

		No of hips	Min	Av	S D	Max
	Normal male	141	15°	32.0°	6.6°	47°
	Normal female	95	19	35.0	7.4	56
	Superior narrowed male	141	18	34.2	7.3	55
I	Superior narrowed female	95	14	33.2	6.7	56
II	Lateral narrowed	24	16	32.4		42
3	Uniformly narrowed	7	20	37.4		46
4	Blurred eyebrow	14	23	33.4		56
5	Change in femoral head shape	5	25	36.7		36
6	Displacement of the femoral head on the neck	7	23	29.2		37

Av Average

S D Standard deviation

Table 1 Age distribution and type of fracture

Age (years)	Total number	Male	Female	Type of fracture		
				Pauwels I	Pauwels II	Pauwels III
10-39	6	6			2	4
40-65	21	11	15	8	7	6
over 65	33	10	23	5	20	8
Total	60	22	38	13	29	18

females mean ages 53 (range 15 to 85) and 68 (range 40 to 83) years respectively (Table 1). The fractures were classified according to Pauwels (1935). Stable fractures belonging to Pauwels group I were displaced or wedged into a valgus position (13 patients) and unstable ones belonging to Pauwels group III were displaced into varus (18 patients). Pauwels group II (29 patients) contained both stable and unstable fractures in a neutral or anatomical position.

Preoperative treatment

All patients were treated with traction before the operation in order to preserve the circulation and the vascular supply to the hip joint and also to alleviate the pain. Preoperative treatment was given to patients with congestive heart disease, hypertension or infections of the respiratory tract.

Operative technique

The fracture was reduced on the operating table under general anesthesia with the aid of an X-ray television screen. Through a small incision in the trochanteric region two thin Smith-Petersen nails were introduced along guide pins hammered into the correct position and the guide pins were removed. The correct placement of the nails is demonstrated in Figure 1 A-D.

Aftertreatment

Fifty-six patients were mobilized on the day after the operation. In 15 cases mobilization was delayed because of poor general health or concomitant diseases. Weight bearing on the operated extremity was allowed within a few days in 56 cases on the day after the operation.

Complications

One patient died 7 days after the operation of a heart infarction and eight patients died within

2 years of the operation from other causes. These patients were excluded from the series. Two cases of postoperative infection were registered and in four cases the operative technique was considered to be imperfect.

Follow-up

Thirty-three patients were hospitalized for less than 3 weeks and 22 between 3 and 4 weeks (Table 2). All of the patients were followed up for more than 2 years. The follow-up period was 2-3 years in 30 cases, 3-4 years in 27 cases and more than 4 years in 3 cases (Table 3).

Table 2 Duration of hospital treatment

Duration (weeks)	Total no of patients	Patients in different age groups		
		10-39 years	40-65 years	over 65 years
1	3		3	
2	31	2	12	17
3	17	1	4	12
4	2	2		3
6-7	4	1	2	1
Total	60	6	21	33

Table 3 Follow-up period

Follow-up (months)	No of patients
24-35	30
36-47	27
over 48	3
Total	60

SUBCAPITAL FRACTURES OF THE FEMUR TREATED WITH TWO THIN SMITH-PETERSEN NAILS

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The results of treatment of 71 patients with subcapital fractures of the femur, fixed with two thin Smith-Petersen nails, are presented after a follow-up time of between 2 and 4 years. Excellent results of treatment were achieved in 39 out of 60 cases and good results in 11 cases. Six cases of ischemic necrosis of the femoral head were recorded, and there were four cases with pseudarthrosis of the femoral neck, one developed because of postoperative infection and three were attributed to an imperfect operative technique. The method is recommended for subcapital femoral neck fractures amenable to closed reduction and internal fixation. Pseudarthrosis may be prevented by good reduction of the fracture and a careful nailing technique.

Key words: femoral neck fractures, fracture fixation, internal fixation

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In the treatment of subcapital fractures of the femur, primary endoprosthesis has been advocated because of the high incidence of late capital necrosis (Trueta 1968). Other surgeons have preferred nailing, claiming that retention of the patient's own femoral head is better than an endoprosthesis (Barnes 1967, Bentley 1968, Garden 1964, Massie 1973, Nicoll 1963). This has focused attention on the methods of nailing, which in turn has resulted in new procedures of fixation (Barnes 1967, Garden 1961, Massie 1964, 1973, Smyth et al 1964). A good surgical technique is most important (Garden 1964). Therefore, the method of nailing should be technically simple, but at the same time a good fixation should be achieved. The method presented in this

paper—fixation with two thin Smith-Petersen nails—seems to fulfill these demands.

MATERIAL

The material includes the first 71 consecutive cases of subcapital fractures of the femur fixed with two thin Smith-Petersen nails made of Vitallium. These nails were originally intended for fixation of femoral neck fractures in children. In the belief that two nails could prevent the appearance of pseudarthrosis, which was often seen following fixation of the fracture with one ordinary Smith-Petersen nail, this fixation technique was adopted in our clinic in 1970 (Riskä & Iivtiläinen 1973).

The follow-up period was insufficient in nine patients who died within 2 years of the operation and in two patients who emigrated. These 11 patients were excluded from the series. Of the remaining 60 patients, 22 were males and 38

Table 4 Results of treatment

Result	Total no of patients	Patients in different age groups			Type of fracture		
		10-39 years	40-65 years	over 65 years	Pauwels I	Pauwels II	Pauwels III
Excellent	39	5	14	20	8	21	9
Good	11	1	3	7	2	5	4
Fair	3		2	1	1	1	1
Poor	7		3	4	1	2	4
Total	60	6	24	32	13	29	18

RESULTS

Results were classified into excellent, good, fair, and poor according to the following criteria

Excellent The patient walked without a limp and there was no pain. The union of the fracture was good without signs of ischemic necrosis of the femoral head.

Good The hip joint was pain-free but the patient had to use a stick when walking outdoors, and had a very slight limp. The fracture was well united without signs of ischemic necrosis of the femoral head.

Fair The patient had to use a stick when walking because of pain in the hip joint. The mobility of the joint was reduced. X-rays showed delayed union of the fracture, or early signs of ischemic necrosis of the femoral head.

Poor The patient used a stick when walking and there was pain in the hip joint both when walking and standing. The mobility of the hip joint was reduced. X-rays showed development of a pseudarthrosis or ischemic necrosis of the femoral head. The operative technique was imperfect.

An excellent result of treatment was recorded in 39 cases with good union of the fracture without signs of ischemic necrosis of the femoral head (Table 4). In 11 cases the result was classified as good. In one of these, a man of 39 with a Pauwels group III fracture, slight pain

in the hip joint was present at the last follow-up examination 2 years and 8 months after the operation because of incipient ischemic necrosis of the femoral head, verified by tomography. Postoperative infection in one case resulted in the development of a pseudarthrosis and the result of treatment was classified as poor (Table 4). An imperfect operative technique in one case resulted in delayed union of the fracture with a painful hip joint. The result was classified as fair. Pseudarthrosis of the femoral neck developed in three additional cases giving a poor result, in one case because of poor reduction of the fracture, and in two cases because of an imperfect nailing procedure. Ischemic necrosis of the femoral head was registered in altogether five cases. The result of treatment was classified as fair in two cases and as poor in three cases. All four cases with pseudarthrosis and the three cases with ischemic necrosis of the femoral head were later treated with endoprosthetic surgery.

DISCUSSION

Meticulous attention to surgical technique and good postoperative care are required in the treatment of subcapital fractures. In our clinic, Nyström nails were previously used for internal fixation

Figure 1
Radiographs of a
59 year old man
with a Pauwels
group II type
fracture of the
femoral neck
treated by two thin
Smith Petersen
nails A B Before
operation C D
Two years and
three months after
the operation



TOTAL HIP REPLACEMENT IN ANKYLOSING SPONDYLITIS

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Eighteen total hip replacements were performed in 10 patients with ankylosing spondylitis. The mean observation time was 3½ years. Seven hips had been operated on before total hip replacement (THR), 6 were ankylosed before THR. The results as regards pain relief and increased walking distance were good. All hips improved in mobility after THR and this improvement was maintained during the observation time. Six of the 10 patients went back to full time work. The differences between patients with ankylosing spondylitis and rheumatoid arthritis, as regards indications for and rehabilitation after THR are discussed.

Key words: ankylosis, arthritis, rheumatoid arthroplasty, hip, rehabilitation, sex, spine rigid, spondylitis, ankylosing, vital capacity, young patients.

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Hip involvement is common in ankylosing spondylitis (AS) and often leads to ankylosis of the hips (Dwosh et al 1976). In AS the spine is usually very rigid, and therefore the decrease in hip mobility cannot be compensated for by movements of the spine. Cup arthroplasty has been tried in ankylosing spondylitis but seems to give disappointing results (Law 1952, Johnston & Larson 1969, Brattstrom et al 1974).

It is generally realized that the problems of total hip replacement (THR) in the rheumatic diseases are different from the problems of THR in osteoarthritis. However, it is not always appreciated that patients with AS differ in many ways from patients with rheumatoid arthritis (RA) as regards indications for and rehabilitation after THR.

1 Patients with AS are usually young and physically more active than patients

with RA. This makes postoperative rehabilitation easier but on the other hand means that the prosthesis will be subjected to greater stresses.

2 In AS, the upper extremities are usually in good condition, which means that the patients can use walking aids effectively and are often able to walk in spite of very bad hips.

3 Stiffness is often a greater problem than pain. By the time hip surgery is needed in AS, the spine is usually quite rigid, which makes the patient very dependent on hip movement for sitting, picking up objects from the floor etc.

4 Vital capacity is reduced because of involvement of the costovertebral joints. This may cause problems during or after general anaesthesia and may limit walking after hip replacement.

5 Improvement in range of motion after THR may be small (Arden et al 1970,

tion of subcapital fractures (Nystrom 1954) but these were inserted into the femoral neck without guide pins and were therefore replaced by two thin Smith-Petersen nails. The results of treatment using this nailing technique were excellent or good in 50 out of 60 patients and good union of the fracture was seen in 56. Six cases of incipient aseptic necrosis of the femoral head were recorded after a follow-up of 2-4 years. However, it may not be possible to avoid, in some cases, the development of late capital necrosis years after the fracture, because this is dependent on the type of fracture and may be on subsequent overstrain of the hip joint (cf. Massie 1973).

In three cases an imperfect operative technique resulted in the development of pseudarthrosis, but this can be avoided by good operative technique. Weight-bearing on the operated limb was allowed on the day after the operation and the hospital stay was less than 3 weeks in 51 cases. In addition, the general condition of the patients was not affected by the nailing procedure, which can easily be carried out, under local anesthesia, if necessary. Thus, if a subcapital fracture of the femoral neck is amenable to closed reduction and internal fixation, this method with two thin Smith-Petersen nails may well be a reasonable choice.

REFERENCES

- Barnes, R. (1967) Fracture of the neck of the femur. *J Bone Jt Surg* 49 B, 607-617.
- Bentley, G. (1968) Impacted fractures of the neck of the femur. *J Bone Jt Surg* 50-B, 551-561.
- Garden, R. S. (1961) Low angle fixation in fracture of the femoral neck. *J Bone Jt Surg* 43-B, 647-663.
- Garden, R. S. (1964) Stability and union in subcapital fractures of the femur. *J Bone Jt Surg* 46 B, 630-647.
- Massie, W. H. (1964) Fractures of the hip. *J Bone Jt Surg* 46-A, 658-690.
- Massie, W. H. (1973) Treatment of femoral neck fractures emphasizing long term follow up observations on aseptic necrosis. *Clin Orthop* 92, 16-62.
- Nicoll, E. A. (1963) The unsolved fracture. *J Bone Jt Surg* 45-B, 239-241.
- Nystrom, G. (1954) Further experience with osteosynthesis of medial fractures of the femoral neck with the aid of three nails ("multiple nailing") with special reference to the indications for reconstructive operations on the hip-joint. *Acta chir scand* 107, 89-112.
- Pauwels, F. (1935) *Der Schenkelhalsbruch. Ein mechanisches Problem. Grundlagen des Heilungsvorganges. Prognose und kausale Therapie.* Ferdinand Enke, Stuttgart.
- Riskä, L. H. & Lyytikäinen, M. (1973) Subcapital fractures of the femur treated with two thin Smith-Petersen nails. Proceedings of the Scandinavian Orthopaedic Society, 36th Assembly, Helsinki. *Acta orthop scand* 44, 115-117.
- Smyth, E. H. J., Ellis, J. S., Mansfield, M. C. & Devcy, P. R. (1964) Triangle pinning for fracture of the femoral neck. *J Bone Jt Surg* 46 B, 664-673.
- Trueta, J. (1968) Die Anatomie der Gefässe des Oberschenkelkopfes und ihre Empfindlichkeit gegenüber traumatischer Schädigung. *Mschr Unfallheilk* 71, 18-28.

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5 Improvement in range of motion after THR may be small (Arden et al 1970,

Year	Authors	Reviewed Pat. Hips	Observation time	Pain relief	Results			Walking	Ankylosis (hips)		Comments
					No pain before or after THIR	Range of motion			Pre op	Post op	
1969	Buchholz	12	20	9	No pain	Improved	Improved	Improved	20	none	
1970	Arden et al	5	9	> 6 months	71.5 per cent good or excellent	Sum total hip motion > 100° in all hips post op	Not evaluated	Not evaluated	?	none	Results graded according to range of flexion and presence of pain
1970	Welch & Charnley	20	33	> 1 year	100 per cent	Sum total hip motion > 100° in all hips post op	Improved	Improved	13	none	
1972	Arden et al	7	10	> 1 year	80 per cent good or excellent		Improved	Improved	2 or more	none	
1972	Harris et al	9	9	> 3 months	78 per cent good or excellent		Not evaluated	Not evaluated	?	none	
1972	Wilde et al	1	1	4 months					1	1	Reports a case of reankylosis after THIR. Hip previously operated with cup arthroplasty
1973	Buchholz & Noack	26	41	> 2 years	Good	Improved	Improved	Improved	?	?	
1975	Halley & Charnley	9	17	> 6 months	100 per cent	88.2 per cent total hip motion post op	Improved	Improved	?	none	82.4 per cent had less than 30° sum total hip motion before THIR
1976	Bisla et al	23	34	> 1 year	Good	Satisfactory in 58.6 per cent	Improved	Improved	21	?	
1976	Heavnick et al	8	16	> 1 year in 14 hips		Poor			1	?	All 3 hips showing clinical reankylosis had previous surgery. Three out of 5 hips with radiological reankylosis had a me-

Table 2 Details about patients

Pat no	Sex	Side	Age at op (years)	Duration of disease at op (years)	Previous operation	Ankylosis before THR	Grade according to the method of Merle d'Aubigné & Postel See also Table 3						Observation time (years)
							Pain	Before THR Walking	Mobility	Pain	At follow-up Walking	Mobility	
1	M	R	not op	—	—	—	1	2	4	6	5	6	23
		L	61	20	—	—	3	2	3	6	5	4	43
2	M	R	55	29	—	—	3	2	1	6	5	4	42
		L	55	29	—	—	3	2	4	6	5	5	27
3	M	R	40	20	—	—	3	3	3	6	5	5	48
		L	44	18	—	—	3	3	3	6	5	4	35
4	I	R	35	11	cup	—	1	1	3	6	1	4	34
		L	35	11	cup	—	3	1	3	6	4	5	26
5	M	R	35	15	—	—	3	2	3	6	3	5	28
		L	35	15	synovectomy	—	3	3	1	6	3	5	—
6	M	R	not op	—	—	—	1	2	—	6	4	5	42
		L	30	10	synovectomy	—	6	2	1	6	1	4	50
7	M	R	23	9	cup	+	6	2	1	6	4	4	52
		L	23	9	—	+	6	2	1	6	1	4	45
8	M	R	20	6	—	+	3	2	1	6	4	5	44
		L	20	6	—	+	3	2	1	6	4	5	46
9	M	R	20	11	—	—	3	3	2	6	4	5	32
		L	21	14	synovectomy	+	6	3	1	6	4	5	58
10	I	R	18	6	—	+	6	2	1	6	1	5	37
		L	20	8	cup	—	3	2	4	6	1	6	27

mean =
38
yearsmean =
32
years

Men 8 patients 14 total hip replacements
 Women 2 patients 4 total hip replacements
 Total 10 patients 18 total hip replacements

Arden et al 1972) and may not last. Some authors warn against the risk of re-ankylosis after hip surgery in AS (Dwosh et al 1976, Resnick et al 1976).

In most reported series, a few THRs in AS are reported together with a much greater number done in RA, osteoarthritis and miscellaneous other diseases. It is usually impossible to see what difference, if any, there is between the results in the different diagnostic categories. Some earlier reports on THIR in AS are listed in Table 1. All these reports except three (Wilde et al 1972, Bisla et al 1976, Resnick et al 1976) include THRs done in diseases other than AS but we have tried to separate the results according to diagnoses.

In this study, patients with AS who had undergone THIR were examined to assess the results of the operation and to find out especially whether hip range of motion had been improved and whether any improvement of this kind had been maintained.

PATIENTS AND METHODS

Patients

Eleven patients with AS underwent THIR in the Department of Orthopaedic Surgery of the University Hospital in Lund from September 1971 to October 1974. The patients were treated in cooperation with the Department of Rheumatology.

One patient died of a myocardial infarction 6 months after THIR and is not included in this study. The others were last examined by one of the authors (Baldursson) in the autumn of 1976. The mean observation time was 3.8 years with a minimum of 2.2 years. Further details about the patients are given in Table 2. Of special interest is the mean age only 32 years.

Indications

Indications for THIR were as follows:

Pain at rest	4
Pain and reduced range of motion	10
Ankylosis without pain	4
Total	18 hips

Before THIR was decided upon the patient and the team thoroughly discussed the patient's problems and the patient was informed about

the expected improvement and the risks connected with the operation.

Operation

General anaesthesia was used. In 11 operations an endotracheal tube could be passed but in seven operations a mask and a pharyngeal tube had to be used. No tracheostomies were done.

The operations were done in an ordinary operating room. Prophylactic anticoagulant treatment was not given. An anterolateral incision was used in 16 operations and a posterolateral incision in two operations. The greater trochanter was not detached. The neck of the femur was divided with an osteotome usually *in situ*. An adductor tenotomy was done in four hips and a tenotomy of the iliopsoas in six hips. The operating time was 120–205 minutes with a mean of 150 minutes. This is longer than the average operating time for THIR in osteoarthritis. Many of the THIRs reported here were technically difficult because of scarring from previous operations or because of ankylosis. A McKee Farrar prosthesis was used in 17 hips and a House prosthesis in one (left hip of patient no. 9, Table 2).

In five THIRs cloxacillin was given before operation and continued after operation. In 12 THIRs antibiotics were given only after the operation. In six of these penicillin was used, cloxacillin in five and tetracycline in one. In one THIR no antibiotics were given.

Time in hospital

The stay in hospital after operation was from 14 to 86 days with a mean of 39 days. This includes the time spent in a rehabilitation clinic by some patients who were sent there upon their discharge from the department of orthopaedic surgery.

Complications

There were no complications related to the anaesthesia. One patient had a postoperative haematoma which was evacuated. Four hips had superficial infections, all of which healed.

RESULTS

The results were assessed according to clinical findings, i.e. pain (Table 4), walking ability (Table 5), mobility (Table 6) and functional capacity (Table 7) and radiological findings.

With regard to pain walking ability

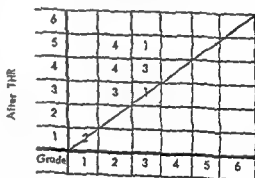
Table 3 Hip grading according to d'Aubigné & Postel

Grade	Pain	Function (walking ability)	Mobility (degrees)
1	Severe and spontaneous	Few yards or bedridden: two canes or crutches	0-30
2	Severe on attempting to walk, prevents all activities	Time and distance very limited with or without canes	31-60
3	Tolerable permitting limited activities	Limited with one cane difficult without cane able to stand long periods	61-100
4	Only after some activity disappears quickly with rest	Long distance with one cane limited without a cane	101-160
5	Slight or intermittent pain on starting to walk, less with activities	No cane but a limp	161-210
II	No pain	Normal	211-260

and mobility, the hips were graded according to the method of d'Aubigné & Postel (1954) in the form used by Halley & Charnley (1975) except that alphabetic prefixes were not used. By this method hip mobility is assessed as the sum of flexion, extension, abduction, adduction, internal rotation and external rotation.

Pain. Four hips were pain free before

Table 5 Walking ability assessed according to the method of d'Aubigné & Postel. See also Table 3

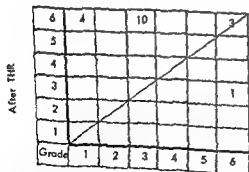


Before THR

Above diagonal line = improved	15
On diagonal line = unchanged	3
Below diagonal line = worse	II
Total	18 hips

THR. These four hips were ankylosed and, in three, a bony ankylosis was present. At the time of the last examination, 17 hips were pain-free. One hip is painful at rest and on weight bearing. The cause of the pain, which started 3 years after THR, is still not clear, but late infection must be suspected.

Table 4 Pain assessed according to the method of d'Aubigné & Postel. See also Table 3



Before THR

Above diagonal line = improved	14
On diagonal line = unchanged	3
Below diagonal line = worse	1
Total	18 hips

Arden et al 1972) and may not last. Some authors warn against the risk of re-ankylosis after hip surgery in AS (Dwosh et al 1976, Resnick et al 1976).

In most reported series, a few THRs in AS are reported together with a much greater number done in RA, osteoarthritis and miscellaneous other diseases. It is usually impossible to see what difference, if any, there is between the results in the different diagnostic categories. Some earlier reports on THR in AS are listed in Table 1. All these reports except three (Wilde et al 1972, Bisla et al 1976, Resnick et al 1976) include THRs done in diseases other than AS, but we have tried to separate the results according to diagnoses.

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With regard to pain, walking ability

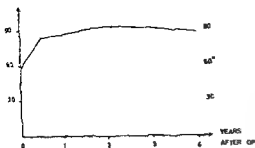


Figure 1 Mean arc of flexion in the 12 hips where some mobility was present before THR

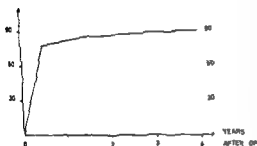


Figure 2 Mean arc of flexion in the 6 hips that were ankylotic before THR

Figure 2 shows in the same way the arc of flexion during the observation time in the six hips that were ankylotic before THR. There was also a relatively rapid increase in mobility in these hips during the first 6 months and after that there

TH

upor

as well as the others during the observation time

Functional capacity Before THR all patients except one were in functional class II according to the classification of the American Rheumatism Association (Steinbrocker et al 1949) but they almost qualified for class III because of hip pain stiffness or deformity.

Six of the 10 patients were working full time at follow up. One patient was working part time. One patient is studying at a university and is expected to

work full-time after graduation. Of the two patients left, one is a 64-year old retired farmer and the other is a 38-year-old housewife incapacitated by general ill health and multiple joint symptoms.

Radiological findings

The radiographs were examined by one of the authors (T.H.O.) with special attention to signs of loosening, infection and ectopic calcifications.

The period of radiological follow-up was between 18 and 58 years with the exception of one patient (No 9) who was last X-rayed 0.9 years after his last hip replacement.

The so-called zone about the cement did not exceed 2 mm in any of the hips. There was no case of ankylosis post-operatively. Small calcifications were found laterally to the femoral neck in five cases. No radiological signs of infection were found. Fracture of the plastic cement around the femoral stem was found in one hip (patient no 2, left hip). This indicates that movement may occur between the prosthesis and the cement in this hip, but as the patient is symptom-free and 60 years old reoperation is not indicated.

In another case (patient no 3, right hip) the femoral part of the prosthesis, with its plastic cement intact, has moved 5 mm in a caudal direction in relation to the femur.

DISCUSSION

Our experience of THR in AS has been encouraging. In contrast to RA patients, AS patients rarely have serious involvement of peripheral joints other than the hips. This, in addition to their young age, means that many AS patients can be rehabilitated to a gainful occupation, whereas, in the case of the RA patients, one must often be content with a pain-free and mobile hip and must accept that the ability to work is unchanged by THR.

Walking ability Table 5 shows the improvement in walking ability after THR. Before THIR, the limiting factor was hip pain or stiffness. After THIR, the limiting factor in at least three patients was poor respiratory function.

In our clinic, patients with THIR are advised not to "throw away the cane",

Table 6 Mobility assessed according to the method of d'Aubigne & Postel. See also Table 5

After THR	6				2	
	5	4	1	2	1	
	4	5		3		
	3					
	2					
	1					
Grade	1	2	3	4	5	6

Before THR

Above diagonal line = improved	18
On diagonal line = unchanged	0
Below diagonal line = worse	0
Total	18 hips

but some patients find the cane unnecessary or that it interferes with their work especially if the work includes walking and carrying. This means that in practice there is no sharp dividing line between grade 4 and 5 (with or without a cane).

Mobility Six hips were ankylosed before THIR. The word "ankylosed" is used to denote absolute absence of movement on clinical examination. Three more hips had only minimal movement, less than 30° total movement in all directions.

The movement of extension-flexion is the most important one of the hip movements. This is also the hip movement that is easiest to measure and where the least error of measurement may be expected. We have therefore selected the arc of flexion to represent hip movement and Figure 1 shows the mean arc of flexion before THIR and during the observation time in the 12 hips where some mobility was present before THIR. The mean arc of flexion before THIR was 58° in these 12 hips. After THIR, there was a gain in movement during the first 6 months and after that the mobility was practically unchanged during the observation time.

Table 7 Functional capacity according to the classification of the American Rheumatism Association (Steinbrocker et al 1949)

		Before hip replacement	After hip replacement
Class I	Complete functional capacity with ability to carry out all usual duties without handicap		5 patients 9 hips
Class II	Functional ability adequate to conduct normal activities despite handicap of discomfort or limited mobility of one or more joints	9 patients 16 hips	4 patients 7 hips
Class III	Functional capacity adequate to perform only little or none of the duties of usual occupation or self care		1 patient 2 hips
Class IV	Largely or wholly incapacitated with patient bedridden or confined to wheelchair permitting little or no self care	1 patient 2 hips	

- Buchholz H W (1969) Die Remobilisation der ankylosierten Hüftgelenke bei der Spondylitis ankylopoetica mit der totalen Endoprothese *Verh Dtsch Ges Rheumatol* 1 178-184
- Buchholz H W & Noack G (1973) Results of the total hip prosthesis design "St George" *Clin Orthop* 95 201-210
- Currey H L F (1970) Osteoarthritis of the hip and sexual activity *Ann rheum Dis* 29 488-493
- Dwosh I L, Resnick, H & Becker W A (1976) Hip involvement in ankylosing spondylitis *Arthr and Rheum* 19 683-692
- Halley D K & Charnley J (1965) Results of low friction arthroplasty in patients thirty years of age and younger *Clin Orthop* 112 180-191
- Harris J, Lightowler C, D R & Todd R C (1972) Total hip replacement in inflammatory hip disease using the Charnley prosthesis *Brit med J* 2 750-752
- Johnston R C & Larson C B (1969) Results of treatment of hip disorders with cup arthroplasty *J Bone Jt Surg* 51 A 1461-1479
- Law W A (1952) Surgical treatment of the rheumatic diseases *J Bone Jt Surg* 34-B 215-225
- Resnick D., Dwosh I L, Goergen T G., Shapiro H F & D'Ambrosia R (1976) Clinical and radiograph "reankylosis" following hip surgery in ankylosing spondylitis *Amer J Roentgenol* 126 1181-1188
- Steinbrocker O, Traeger C H & Batterman H C (1949) Therapeutic criteria in rheumatoid arthritis *J Amer med Ass* 140 659-662
- Todd R C, Lightowler C, D R & Harris J (1973) Low friction arthroplasty of the hip joint and sexual activity *Acta orthop scand* 44 690-693
- Welch R B & Charnley J (1970) Low friction arthroplasty of the hip in rheumatoid arthritis and ankylosing spondylitis *Clin Orthop* 72 22-32
- Wilde A H, Collins H R & Mackenzie A H (1972) Reankylosis of the hip joint in ankylosing spondylitis after total hip replacement *Arthr and Rheum* 15 493-496

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Sexual problems are common with these young patients, as in other diseases where hip pain and stiffness occur (Curry 1970, Todd et al 1973) THR can be a great help by removing hip pain and stiffness, thus making it physically possible for the patient to have a normal sex life. However, the patient's worries and hopes often remain unspoken and so are unknown to the surgeon, who rarely directs his questions towards sexual matters when discussing the patient's problems. Instead, the discussion centres on other aspects of hip function, such as walking and sitting, which the patient may in fact be less concerned about. As the patient and the surgeon have not discussed the sexual aspects of THR, there may remain unsolved problems that could have been solved easily and quickly by informing the patient. For instance, a female patient may abstain from sexual intercourse because of unnecessary fear of damaging her prosthesis.

As regards pain relief and improvement in ability to walk, the results are comparable to the results of THR in other patient categories. All hips have improved in range of motion and, what is interesting, have maintained that improvement during the observation period. The hips that had been operated upon before or were ankylosed before THR were no exceptions. In some cases where a patient for some reason did not exercise, a temporary decrease in hip mobility was seen. The mobility could in all instances be brought up to the previous level by a period of intensive training. We consider that the most important factor in preventing deterioration of hip mobility after replacement is patient instruction and regular supervision, preferably by a team consisting of an orthopaedic surgeon, a rheumatologist and a physiotherapist. The improvement in range of motion by THR can be maintained, but this means a great deal of

hard work for the patient and perhaps for the physiotherapist, who must see the patient regularly. If poor vital capacity seems to limit the patients' walking distance, breathing exercises may be useful and should be tried.

Total hip replacement can be very important in the rehabilitation of patients with AS, but it must be remembered that these young and active patients with their rigid spines do not treat their prosthesis gently and are very dependent upon hip mobility. They must be kept under supervision for a long time after THR, probably for the rest of their lives both to discover complications (eg loosening or fracture of the prosthesis) in time and also to see that mobility of the replaced hips is maintained.

ACKNOWLEDGEMENTS

This study, which is part of a project concerning hip surgery in the rheumatic diseases, was financially supported by grants from Riksförbundet mot reumatism, Föreningen för bistånd åt vanföra i Skåne, Signe och Reinhold Sunds stiftelse, Stiftelsen konsul Thure Carlssons Minde.

REFERENCES

- Arden G P, Taylor A R & Ansell H M (1970) Total hip replacement using the Keene-Farfar prosthesis in rheumatoid arthritis. Still's disease and ankylosing spondylitis. *Ann rheum Dis* 29 1-4.
- Arden G P, Ansell B M & Hunter M J (1972) Total hip replacement in juvenile chronic polyarthritis and ankylosing spondylitis. *Clin Orthop* 84 130-136.
- Aubigné R M & Postel M (1954) Functional results of hip arthroplasty with acrylic prosthesis. *J Bone Jt Surg* 36 A 451-475.
- Bisla R S, Ranawat C S & Inglis A T (1970) Total hip replacement in patients with ankylosing spondylitis with involvement of the hip. *J Bone Jt Surg* 52 A 233-238.
- Brattstrom H, Cedell C A, Hagstam A & Lindén H (1974) Cup arthroplasty in patients with rheumatoid arthritis. *Acta orthop scand* 45 89-96.



Figure 1 Sinogram of right hip showing cavity around neck of femoral prosthesis Note calcified mesenteric nodes



Figure 2 Sinogram of right hip defining branching sinus

negative for tubercle bacilli. The patient was treated with intramuscular Streptomycin 0.5 g daily for 2 months and Rifampicin 450 mg daily and Isoniazid 300 mg daily (to be continued for 18 months). Eight weeks after beginning anti-tuberculous therapy the groin sinus was healed and the ESR had fallen to 45 mm/hour. It fell to 23 mm/hour after 6 months of the therapy. She had 70° of active hip flexion and was able to walk with little pain.

DISCUSSION

A case of tuberculosis arising in a joint that had undergone prosthetic replacement is described. It is assumed that the tuberculous infection in the hip developed following a bacteraemia secondary to activation of a latent tuberculous

focus almost certainly in the mesenteric glands. That the hip contained a prosthesis may have made it susceptible to bacteraemic infection. At the original arthroplasty, operative findings were consistent with osteoarthritis, though the possibility of tuberculosis of the proximal femur has to be considered. It should be noted that healing of the sinus occurred without necessitating removal of the prosthesis. Although rare, tuberculosis should be excluded as a cause of delayed infection in a joint which contains a prosthesis.

TUBERCULOSIS AS A LATE COMPLICATION OF TOTAL HIP REPLACEMENT

C. J. MCCURROUGH

Department of Orthopaedic Surgery, Princess Margaret Hospital, Swindon, Wilts, U.K.

A case of tuberculosis developing in a hip joint which had undergone total prosthetic replacement arthroplasty 7 years previously is described. The patient had no manifestation of active systemic tuberculosis although calcified mesenteric nodes were noted on abdominal X-ray. It is assumed that hip joint infection occurred during a bacteremia following activation of a latent tuberculous focus in the mesenteric lymph nodes.

Key words: tuberculosis, hip arthroplasty.

Accepted 6 v 77

Delayed infection of joints that have undergone prosthetic replacement arises following contamination at the time of original surgery (Charnley & Elstekhar 1969) or from metastatic spread from a septic focus elsewhere in the body (Hall 1974, Parsons 1971). A case of tuberculosis developing in a hip joint in which a total hip prosthesis had been inserted 7 years previously is described. No similar case can be found on review of the literature.

CASE REPORT

In March 1968 a 70 year old lady underwent a right Rintell total hip replacement for osteoarthrosis. Operative findings revealed eburnation of the femoral head and a shallow worn acetabulum. When reviewed in December 1969 she had a good range of pain free movements of the hip.

In November 1975 she presented with a 4 cm swelling in the right groin lateral to the femoral artery and attached to the underlying muscles. At operation the swelling found to lie between sartorius and pectineus could not be enucleated

but its caseous contents were evacuated. The cyst wall and its contents were sterile on routine bacteriological culture and tubercle bacilli were not cultured or seen on Ziehl-Nielsen stain although the operative findings suggested a psoas abscess. Histology revealed non specific chronic inflammation. X-ray of the lumbar spine was normal. Postoperatively the patient developed a pyrexia and a purulent discharge from the wound *Staph. pyogenes* being cultured.

Four weeks postoperatively despite therapy with cloxacillin there was a persistent staphylococcal discharge from the groin wound. A sinogram (Figures 1 and 2) defined a branching sinus arising from a cavity adjacent to the head of the Ring prosthesis. On January 22nd the sinus was biopsied and laid widely open the deep tract being followed to the junction of the femoral neck and its prosthesis. The tissue was sterile on routine culture and histology revealed non specific subacute inflammation.

The patient's hip remained extremely irritable and her ESR was raised to 100 mm/hour. Six weeks after the sinus exploration Myco tuberculosis was isolated on culture from the biopsy sinus wall and acid/alcohol fast bacilli were also identified by Ziehl-Nielsen stain. A leaf test was strongly positive (Grade III) and calcified mesenteric nodes were noted on X-ray in the right iliac fossa. Chest X-ray was clear and sputum and early morning urine specimens were

LOAD BEARING CHARACTERISTICS OF THE PATELLO-FEMORAL JOINT

LARRY S MATTHEWS, DAVID A SONSTEGARD & JOHN A HENKE

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This study of normal patello femoral biomechanics defines some functional specifications which may be useful in future total knee prosthesis design. Serial lateral X rays of 15 fresh knees and their patellar mechanisms at several flexion angles provided definition of the direction of the resolved patello femoral forces. Assuming that the patella acts as a frictionless pulley, the magnitude of the patello femoral forces during several activities was calculated using data from Morrison (1970) and Smidt (1973). It ranged between 421 and 3420 newtons for the various activities and for isometric exercise. A methylene blue contact print technique was used to measure the bearing areas. These data indicate that between 13 and 38 per cent of the patellar surface bears joint loadings. Patello femoral contact stresses were calculated to range from 1.28 to 12.6 N/mm². A 696 newton man climbing stairs would, for example, generate a patello femoral force of 1754 newtons and would experience patello femoral contact stresses between 3.73 and 6.87 N/mm². Stress values were equal to or in excess of anticipated tibial femoral stresses. The high patello-femoral load values, the small bearing surfaces, and the consequent significant stress magnitudes indicate the need for caution in development of a patello femoral joint prosthetic replacement.

Key words: biomechanics, knee joint, knee joint forces, patella prosthesis.

Accepted 16 v 77

patello-femoral articulation may detract from the expected relief of pain after these procedures. Rational design considerations in the development of a pro-

thesis which addresses this problem require knowledge not only of the anatomy of the joint, but also of the functional stresses normally present across the bearing surfaces. Although considerable information is available regarding the anatomy, biomechanics, and pathology of the patello-femoral articulation, we were unable to find adequate published experimental values for patello-femoral contact areas and for contact stresses at

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REFERENCES

- Charnley, J. & Eftekhari, N (1969) Post operative infection in total prosthetic replacement arthroplasty of the hip joint *Brit J Surg* 56, 641.
- Hall, A J (1974) Late infection about a total knee prosthesis *J. Bone Jt Surg* 56 B, 144
- Parsons, D W (1971) In discussion *Proc Roy Soc Med* 64, 639

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Key words: biomechanics, knee joint, knee joint forces, patella, prosthesis.

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Most available total knee joint prostheses treat only the tibial femoral portion of the knee joint. Residual pathology at the patello-femoral articulation may detract from the expected relief of pain after these procedures. Rational design considerations in the development of a pros-

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- Hall A J (1974) Late infection about a total knee prosthesis *J Bone Jt Surg* **56B** 144
- Parsons, D W (1971) In discussion *Proc Roy Soc Med* **III** 639

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Figure 4 Typical photographs of specimens A single contact area 30° knee flexion The number of contact area determinations that are possible for one specimen is shown



walking up and down a one to six ramp and going up and down stairs similar isometric quadriceps forces at defined knee flexion angles have been reported by Smidt (1973). These values were used to calculate the patello femoral contact forces in Table 1.

In order to determine contact stress direct measurement of the patello femoral contact areas was necessary. For our 15 fresh specimens the patella was surgically released from its medial and lateral proximal capsular attachments. It was painted with methylene blue or red instrument ink. A desired knee flexion angle was selected. The patella was returned to its normal position for the selected angle and secured in position with manual tension on the quadriceps aponeurosis. A force of 25 kg was then manually applied normal to the patello femoral contact point and coaxial with the predetermined patello femoral force vector F_{pf} . The resulting contact print (Figure 4) of the force bearing area was photographed.

A lens to object distance of 18 inches was used for all photographs. A centimeter ruler was positioned level with the area of interest and included in all photographs. Multiple exposures were made of each specimen to be sure that the contact areas of interest would be perpendicular to the focal axis. The resulting slides were enlarged until the centimeter markings on the ruler could be superimposed on centimeter graph paper. The contact areas were traced and the areas enclosed by the tracings were determined by planimetry.

Although Aglietti et al (1975) have reported

that in a limited number of experiments on two specimens patello femoral areas were only slightly affected by increases in quadriceps force we were concerned that due to the deformability of articular cartilage our manually applied patello femoral load of 25 kg was non physiologic and that our measured contact areas might be smaller than those experienced by the knee during normal activities. Accordingly prepared specimens were fixtured in an Instron testing machine where loads between 118 and 1472 newtons were sequentially applied to the patella. These experiments demonstrated that a small but significant increase in measured areas results from the higher loads applied to the patella along the F_{pf} vector line. A similar series of experiments determined that the time period of loading caused no significant differences in measured areas over a 6 second to 2 minute span. Subsequent specimens were loaded to 893 newtons at various knee flexion angles for 8 seconds. Total patellar articular areas were determined by the same technique.

RESULTS

The average and range for total patello femoral contact areas at all measured knee flexion angles are presented in Figure 5 A. The percentage of the average total patellar articular surface in contact with the femur is recorded. The influence

this articulation during normal activities. This study was initiated to define these quantities which may be useful in the development and pre-clinical testing of prostheses designed to treat this articulation.

MATERIALS AND METHODS

Quantification of patello femoral contact stresses depends upon the force normal to the touching articular surfaces and upon the area of contact itself. Fifteen fresh grossly normal cadaver lower limbs were minimally dissected. Metallic markers were placed at the centers of the insertions of the patellar tendon on the tibia and patella, at the center of the insertion of the quadriceps mechanism on the superior pole of the patella and at the center of the quadriceps musculotendinous junction approximately 6 cm above the patella. The extensor mechanism was manually pre-tensioned and lateral roentgenograms made at 15 degree increments from full extension to full flexion.

The knee joint angle, α was determined by drawing lines along the central axes of the tibia and femur (Figure 1A). Lines connecting the two metallic markers in the patellar tendon and in the quadriceps aponeurosis respectively defined an angle β (Figure 1B); the patellar

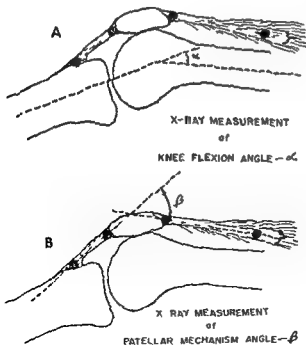


Figure 1 Radiographic method of determination of knee flexion angle α and patellar mechanism angle β .

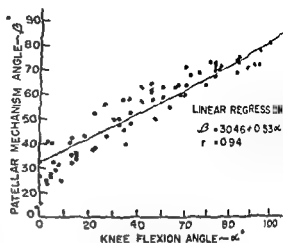


Figure 2 The relationship between the knee flexion angle and the patellar mechanism angle.

mechanism angle β (Figure 2) was plotted and subjected to exponential, power series and linear regression analysis. The latter provided the best data fit and this relationship was used in the remainder of the study.

If quadriceps force F_Q is assumed to be sustained equally by the quadriceps aponeurosis, patella and the patellar tendon, and if the patellar mechanism angle β , is known the normal patellar contact force, the force of the patella against the distal femur F_{pt} , may be calculated to the equation $F_{pt} = 2F_Q \sin \beta/2$ (Figure 3).

Morrison (1970a and b) has reported maximum quadriceps forces and associated knee flexion angles for five activities—level walking

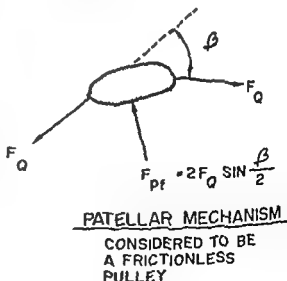
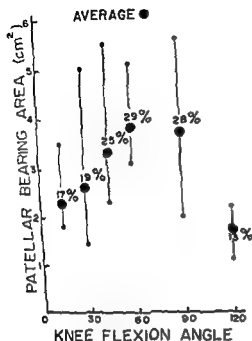


Figure 3 Method of calculation of patello femoral force.

A



B

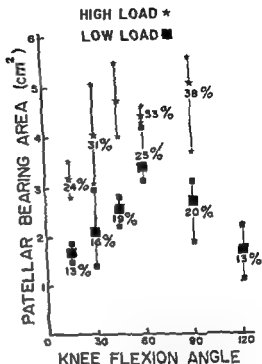


Figure 3 A The averages and ranges of experimentally determined contact areas from all specimens at all knee flexion angles B The experimentally determined effect of the patello femoral loading conditions

of low and high patello femoral load ing conditions is presented in Figure 5 B.

An overall summary of our experi mental data and contact stress calcula tions is presented in Table 1. Quadriceps forces are from the reports of Morrison (1907) and b) and Smidt (1973). The tibial femoral contact areas are from the report of Kettelkamp & Jacobs (1972). The patello-femoral forces were calcu lated from the equation $F_p = 21 F_q \sin \beta / 2$ where F_p is the patello femoral force, F_q is the quadriceps force and β is the patellar mechanism angle determined as previously described. Patello femoral contact area as measured are reported here as well as the averages of those measured under low load experiments, high load experiments and the overall

average for all experiments. Patello femoral contact stresses were calculated from data by the equation: contact stress

$$= \frac{\text{force moment to surface}}{\text{surface area}}$$

and are presented as they were influenced by the above loading conditions.

DISCUSSION

Our experimental results and calcula tions from available data indicate that patello-femoral forces are generally less than tibial femoral forces (Morrison 1970 a, b) during normal activities and during maximum isometric quadriceps contraction (Smidt 1973). We observed that the patella rarely touches the articular

Table 1 *Patello femoral and tibial femoral contact forces areas and stresses compared*

Quadriceps force data from	Activity	Knee joint angle (degrees)	Patellar mechanism angle (degrees)	Quadriceps force (Newtons)	Tibial femoral contact force (Newtons)	Tibial femoral contact areas (millimeters ²)	Tibial femoral contact stress (N/mm ²)
Morrison (1970 a 1970 b)	Walking	15	38	647	2109	660	3.2
	Up ramp	30	46	785	2786	560	5.0
	Down ramp	15	38	1923	2786	660	4.2
	Up stairs	45	54	1923	2963	560	5.3
	Down stairs	60	62	1687	2668	560	4.8
	Isometric	5	33	1393	1294	—	—
Smidt (1973)	Quadriceps	15	38	1776	1648	660	1.9
	Contracture	30	46	2168	2040	560	3.6
		45	54	2433	2325	560	4.1
		60	62	2530	2462	560	4.4
		90	78	2717	2698	560	4.8
				Patello femoral contact force (Newtons)	Patello femoral contact areas (millimeters ²)	Patello femoral contact stress (N/mm ²)	
Morrison (1970 a 1970 b)	Walking	15	38	647	422	170	1.3
	Up ramp	30	46	785	618	210	1.5
	Down ramp	15	38	1923	1265	170	1.5
	Up stairs	45	54	1923	1756	260	3.9
	Down stairs	60	62	1687	1746	340	3.7
	Isometric	5	33	1393	795	340	5.2
Smidt (1973)	Quadriceps	15	38	1776	1158	170	3.6
	Contracture	30	46	2168	1697	210	4.2
		45	54	2433	2207	260	4.6
		60	62	2530	2609	340	4.6
		90	78	2717	3424	270	7.8
					Low load	Average load	High load
Morrison (1970 a 1970 b)	Walking	15	38	647	170	230	320
	Up ramp	30	46	785	210	260	410
	Down ramp	15	38	1923	170	230	320
	Up stairs	45	54	1923	260	330	480
	Down stairs	60	62	1687	340	380	440
	Isometric	5	33	1393	—	—	—
Smidt (1973)	Quadriceps	15	38	1776	170	230	320
	Contracture	30	46	2168	210	260	410
		45	54	2433	260	330	480
		60	62	2530	340	380	440
		90	78	2717	270	370	510
					Low load	Average load	High load

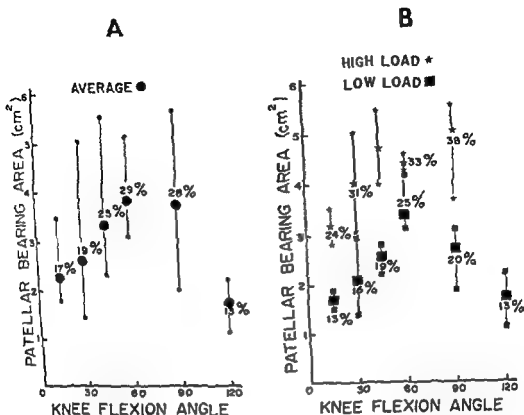


Figure 3 A The averages and ranges of experimentally determined contact areas from all specimens at all knee flexion angles B The experimentally determined effect of the patello-femoral loading conditions

of "low and high patello-femoral loading conditions is presented in Figure 3 B.

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average for all experiments. Patello-femoral contact stresses were calculated from data by the equation: contact stress

$$= \frac{\text{force moment to surface}}{\text{surface area}}$$

and are presented as they were influenced by the above loading conditions.

DISCUSSION

Our experimental results and calculations from available data indicate that patello-femoral forces are generally less than tibial femoral forces (Morrison 1970 a, b) during normal activities and during maximum isometric quadriceps contraction (Smidt 1973). We observed that the patella rarely touches the articular

ular surface of the femur at full knee extension. Patello-femoral contact areas were less than total tibial-femoral contact areas for all degrees of knee flexion under all loading conditions (Kettelkamp & Jacobs 1972). It is of interest that our values for patello-femoral contact areas are in generally good agreement with those reported by Aghetti et al. (1975) using a casting technique employing the injection of acrylic cement into the joint with simulated quadriceps forces from zero to 5400 newtons.

Bearing surface contact stress is of great importance in prosthetic joint design. These studies indicate that the patello-femoral contact stresses are similar to those of the tibial-femoral joint during normal activities. Under all loading conditions, and for all knee flexion angles, patello-femoral stresses were considerably greater than tibial-femoral stresses during isometric quadriceps contraction. A recent report by Walker & Erkman (1975) proposes a load bearing role for the menisci with a total stressed area of up to 12 cm² observed in normal knees. If a load bearing function of the menisci is confirmed, then the patello-femoral contact stresses would be proportionately much greater than tibial-femoral stresses.

A prosthesis to treat the patello-femoral as well as the tibial femoral articulations of the knee must necessarily be designed to function under these anatomically imposed high stress conditions.

High patello-femoral load values, small patello-femoral bearing surfaces and the resultant high stress magnitudes indicate the need for caution in the design and development of a patello-femoral component for a total knee joint replacement prosthesis.

REFERENCES

- Aghetti P, Insall J, Waller, P S & Trent P (1975) A new patella prosthesis. *Clin Orthop* 107, 175-187.
- Kettelkamp D B & Jacobs, A W (1972) Tibio-femoral contact areas—determination and implications. *J Bone Jt Surg* 54 A 349-361.
- Morrison J B (1970) The mechanism of the knee joint in relation to normal walking. *J Biomech* 3 61-61.
- Morrison J B (1970) The mechanics of muscle function in locomotion. *J Biomech* 3 431-451.
- Smidt G I (1973) Biomechanical analysis of knee flexion and extension. *J Biomech* 6 79-92.
- Walker P S & Erkman M J (1975) The role of the menisci in force transmission across the knee. *Clin Orthop* 109 184-192.

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OSTEOCHONDRITIS DISSECANANS OF THE KNEE

A Case Report of an Unusual Lesion on the Lateral Femoral Condyle

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A case of osteochondritis dissecans of the knee is described in which the site of the lesion on the supero-medial aspect of the lateral femoral condyle is unique. This case supports the theory that direct recurrent minor trauma causes osteochondral fractures which remain ununited producing the characteristic lesion.

Key words: osteochondritis dissecans lateral condyle of femur

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Osteochondritis dissecans is found most commonly in the knee and the classical site lies on the medial femoral condyle. However a small percentage of lesions are found either on the infero-central or anterior aspects of the lateral femoral condyle (Green 1966, Aichroth 1971, Scott & Stevenson 1971, Lindholm 1974, Lindholm & Pylkkanen 1974). A lesion on the supero-medial aspect of the lateral femoral condyle has not been described before in the literature.

including the patellar apprehension test were negative. X-rays revealed osteochondritis of the lateral femoral condyle with at least one loose body (Figures 1 and 2).

Exploration of the knee was carried out soon afterwards and the osteochondritis dissecans was found to be in a most unusual site (Figure 3). There was a large loose fragment in a crater on the supero-medial aspect of the lateral femoral condyle. Three smaller loose bodies were recovered from different parts of the joint space. The large fragment and crater were prepared and the fragment fixed in position with two small pins (Figure 4). The patient made an uneventful recovery.

CASE REPORT

A 17 year old male sustained a twisting injury to his right knee while playing tennis. The knee was painful on the lateral aspect and some hours later began to swell. Symptoms and signs subsided over the next few days. One month later while playing football he had a similar episode. One month after that, while playing hockey the knee became swollen and painful, however the swelling did not subside and for a number of days the knee was locked. He presented at the out-patient department 6 months after these episodes with a history of repeated locking and swelling in his right knee. Examination revealed tenderness over the lateral femoral condyle and a moderate effusion. Quadriceps wasting amounted to 3 cm. All other tests in-

DISCUSSION

Sir James Paget (1870) was the first to describe this lesion as a 'quiet necrosis'. König (1888) was the first to call it osteochondritis dissecans and both men thought the lesion was the end result of trauma. Many theories have been discussed since that time. An ischaemic theory was advocated by Reiger (1920), Axhausen (1922) and Watson Jones (1932). However, the demonstration of a rich anastomotic blood supply in the femoral condyles by Rogers & Gladstone (1930) made a vascular lesion secondary

ular surface of the femur at full knee extension. Patello-femoral contact areas were less than total tibial-femoral contact areas for all degrees of knee flexion under all loading conditions (Kettelkamp & Jacobs 1972). It is of interest that our values for patello-femoral contact areas are in generally good agreement with those reported by Aghetti et al (1975) using a casting technique employing the injection of acrylic cement into the joint with simulated quadriceps forces from zero to 5400 newtons.

Bearing surface contact stress is of great importance in prosthetic joint design. These studies indicate that the patello-femoral contact stresses are similar to those of the tibial-femoral joint during normal activities. Under all loading conditions, and for all knee flexion angles, patello-femoral stresses were considerably greater than tibial-femoral stresses during isometric quadriceps contraction. A recent report by Walker & Erkman (1975) proposes a load bearing role for the menisci with a total stressed area of up to 12 cm² observed in normal knees. If a load bearing function of the menisci is confirmed, then the patello-femoral contact stresses would be proportionately much greater than tibial-femoral stresses.

A prosthesis to treat the patello-femoral as well as the tibial femoral articulations of the knee must necessarily be designed to function under these anatomically imposed high stress conditions.

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REFERENCES

- Aghetti P, Insall J, Walker P & Trent P (1975) A new patella prosthesis. *Clin Orth* **107**, 175-187.
- Kettelkamp, D B & Jacobs, A W (1972) Tibio-femoral contact areas—determination and implications. *J Bone Jt Surg* **54 A** 349-351.
- Morrison J B (1970) The mechanism of the knee joint in relation to normal walking. *J Biomech* **3** 51-61.
- Morrison, J B (1970) The mechanics of muscle function in locomotion. *J Biomech* **3** 431-451.
- Smidt, G I (1973) Biomechanical analysis of knee flexion and extension. *J Biomech* **6** 79-92.
- Walker P & Erkman M J (1975) The role of the menisci in force transmission across the knee. *Clin Orthop* **109** 184-192.

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Figure 1. X-ray of knee postoperatively showing the fragment reduced and held in place with Smith pins.

O'Donoghue (1966) stressed that patellar trauma only produced acute osteochondral fractures.

This case would suggest that the lesion in this very unusual site could have been caused by recurrent minor trauma by the patella on the lateral femoral condyle. If the patellofemoral joint had been unstable then one would have expected a lesion on the lateral aspect of the condyle. This medial lesion was caused by repeated minor trauma causing repeated osteochondral fractures which remain ununited producing the characteristic histology of reparation and repair described by Chiroff & Cooke (1975).

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REFERENCES

- Achroth P (1971) Osteochondritis dissecans of the knee. A clinical survey. *J Bone Jt Surg* 53 B 440-447.
- Achroth P (1971) Osteochondral fractures and their relationship to osteochondritis dissecans of the knee. *J Bone Jt Surg* 53 B 448-454.
- Achhausen O (1922) Die Aetiologie der Koller'schen Erkrankung der Metatarsalköpfe. *Beitr Klin Chir* 126 451-476.
- Chiroff H T & Cooke C P (1975) Osteochondritis dissecans. A histological and micro-radiographic analysis of surgically excised lesions. *J Trauma* 15 689-696.
- Farbank H A T (1933) Osteochondritis dissecans. *Brit J Surg* 21 67-82.
- Green J H (1966) Osteochondritis dissecans of the knee. *J Bone Jt Surg* 48 B 80-91.
- Hong (1885) Ueber freie Körper in den Gelenken. *Desch Z Chir* 27 90-103.
- Langenskiöld A (1935) Can osteochondritis dissecans arise as a sequel of cartilage fracture in early childhood? *Acta chir scand* 109 206-209.
- Lindholm T S (1974) Osteochondritis dissecans of the knee. *Ann Chir Gynaec Fenn* 63 69-76.
- Lindholm S & Pylkkanen P (1974) Internal fixation of the fragment of osteochondritis dissecans in the knee by means of bone pins. *Acta chir scand* 140 625-629.
- O'Donoghue H (1966) Chondral and osteochondral fractures. *J Trauma* 6 469-481.
- Payel J (1870) On the production of some of the loose bodies in joints. *St Bart's Hosp Rep* 6 1-4.
- Rieger H (1920) Zur Pathogenese von Gelenkmausen. *Woch Med Wochr* 67 719-720.
- Rogers H M & Cladstone H (1950) Vascular anomalies and arterial supply of the distal end of the femur. *J Bone Jt Surg* 32 A 867-874.
- Scott H J & Stevenson C A (1971) Osteochondritis of the knee in adults. *Clin Orthop* 70 82-86.
- Smith J S (1968) *Osteochondritis dissecans*. p 3. Livingstone, Edinburgh and London.
- Tallqvist G (1962) The reaction to mechanical trauma in growing articular cartilage. *Acta orthop scand* Suppl 53.
- Watson Jones Sir H (1952) *Fractures and joint injuries*. 4th ed. Vol 1. p 97. Livingstone, Edinburgh and London.



Figure 1 X-ray of the knee showing osteochondritis dissecans of the lateral femoral condyle and a loose body in the suprapatellar pouch



Figure 2 Sky-line X-ray which shows osteochondritis dissecans on the lateral condyle



Figure 3 Photograph of lateral condyle showing the area of osteochondritis dissecans in a most unusual site and two loose bodies in the suprapatellar pouch

to embolic phenomena unlikely. Trauma due to impingement of the tibial spine on the femoral condyles was suggested as the cause of the lesion by Fairbank (1933) and Smillie (1960). In an excellent review Green (1966) clearly defined the difference between acute osteochondral fracture and osteochondritis dissecans. Recurrent minor trauma can cause stress fatigue in the subchondral bone and produce the features of osteochondritis dissecans. Langenskiöld (1933) produced such lesions in dogs and his work was later confirmed by Tallqvist (1962) and Aichroth (1971).

Green (1966) suggested that lesions on the lateral femoral condyle were due to trauma caused by the patella but

Table 1 Findings of operation graded according to Collins 0 = no cartilage destruction

Type of cruciate ligament rupture	Duration of condition	Collins' grade					Total no of patients
		0	I	II	III	IV	
Anterior cruciate	$\frac{1}{2}$ to < 2 years	13	6	2			21
	2 to 3 years	4	5	2	1		12
	> 3 years	3		6	1		10
Posterior cruciate	1 and $5\frac{1}{2}$ years	1		1			2
Both	2 17 and 21 years					3	3
No of patients		21	11	11	2	3	48

three cases of meniscectomy, four explorations and one tibial osteotomy plus debridement of the joint.

Methods. During the operation a description was made of the injury to the ligaments and menisci and the state of the articular cartilage and the presence of osteophytes was noted. Akl back (1963) recommended radiography of the knee joint during weight bearing in order to disclose narrowing of the articular space. That this examination is lacking in most of the cases is irrelevant as the pathoanatomy of the cartilage was examined directly during surgery. On the basis of this description the cartilage destruction was graded according to Collins (1949).

Grade I: superficial destruction of cartilage tangential flaking, early fibrillation and small blisters or grooves. No marginal hyperplasia of bone or cartilage.

Grade II: more extensive cartilage destruction but still confined to pressure and movement areas and without denudation of bone. Deep fibrillation and marked loss of cartilage substance. Early marginal hyperplasia.

Grade III: denudation and usually eburnation of bone in one or more pressure areas though regions of unaffected cartilage often remain. Obvious osteophytes at joint margins.

Grade IV: complete loss of cartilage from large areas of the joint surface. Eburnation of exposed bone, epiphyseal osteophytes, remodelling of the contour of the bone ends.

Conventional a.p. and lateral radiographs were studied for osteophytes. Felsenreich's sign, i.e. deformity of the tubercles of the intercondylar eminence (Felsenreich 1934) and structural changes in bone cysts and sclerosis. The healthy knee was used as a control.

In order to see both the radiographical and operative findings as a combined measure of development of osteoarthritis the suggestions of Hult (1969) have been followed. As Collins

grade I and II are clinically silent and osteophytes without other X-ray changes are not sufficient to allow a firm diagnosis of osteoarthritis (Hult 1969, Danielsson & Hjersborg 1970), these groups have been given a different designation on the diagram in Figure 1. Collins' grade III and IV and radiographical findings of structural bone changes, varus deformity or joint space narrowing (as defined by Aklback) have been used as sufficient criteria to allow a firm diagnosis of significant arthrosis (black columns in Figure 1).

The findings were correlated with the duration of knee instability and with the patient's age at onset of symptoms. In addition, earlier meniscectomy was taken into consideration as this could influence development of osteoarthritis (Johnson *et al.* 1974).

FINDINGS

The patients were grouped as shown in Table 1. 13 patients with rupture of the anterior cruciate ligament (group 1), two patients with rupture of the posterior cruciate ligament (group 2) and three patients lacking both anterior and posterior ligaments (group 3). It appears from Table 1 that undamaged cartilage became less frequent as the duration of symptoms increased, so it can be assumed that cartilage destruction is a progressing phenomenon in these knees. If only one of the cruciate ligaments is lacking, the process is relatively slow, if both are lacking the process is quick and pronounced—all knees in group 3 belong to grade IV.

OSTEOARTHRISIS FOLLOWING INSUFFICIENCY OF THE CRUCIATE LIGAMENTS IN MAN

A Clinical Study

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Based on a series of 48 patients with old untreated ruptures of one both cruciate ligaments the development of osteoarthrotic changes was demonstrated by radiography and at operation. The changes were similar to those seen in animal experiments and developed in the same sequence. Osteophytes occurred in 1 knee with anterior cruciate ligament insufficiency after about 2 years, significant osteoarthrotic changes occurred after longer periods and particularly in 1 knee with damage to both cruciate ligaments.

Key words: cruciate ligaments, gonarthrosis, knee osteoarthrosis

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A matter of current interest to the orthopaedic surgeon is to what degree an untreated rupture of the anterior and/or posterior cruciate ligaments may cause osteoarthrotic changes in the knee joint of man. Section of the cruciate ligaments in experimental animals causes structural changes in the joint cartilage and bone (Magnuson 1941, Hulth et al 1970, Marshall & Olsson 1971, Bohr 1976) but because the gait and weight bearing as well as the physical activity in general, and the speed of physiological aging processes, are so different in the joints of animals and man a clinical study of the processes in man may help to elucidate this problem.

PATIENTS AND METHODS

Definition. The term osteoarthrosis is used here to describe a condition in which aseptic destruc-

tion of the articular cartilage leads to denudation of the subchondral bone with subsequent structural changes in the form of cysts and sclerosis. To the clinician the essential symptom is pain. To the pathologist destruction of cartilage is a necessary finding (Collins 1949) while to the radiologist the condition is linked first and foremost with narrowing of the joint space and also with the above mentioned structural changes in the subchondral bone (Ahlbäck 1968). The presence of osteophytes alone cannot be taken as a significant sign of osteoarthrosis (Danielsson & Hernborg 1970).

Patients. All the patients included in the present study were operated on by the author during the years 1974 to 1975. The criterion for inclusion was rupture of one or both cruciate ligaments with symptoms lasting for more than 6 months. The series comprises 48 patients of whom only seven are females. Thirty six patients were below the age of 30 at the time of operation and 44 patients below the age of 40, the mean age was 29 ranging from 16 to 73. There were no bilateral cases. The type of surgical repair included 33 cases of the Jones procedure for replacement of the anterior cruciate ligament, seven other kinds of ligament plastic

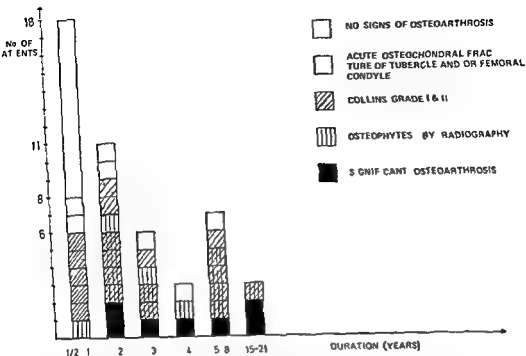


Figure 1 Duration of insufficiency of cruciate ligaments related to osteoarthritis in 48 patients. Significant arthritis means that the knee was classified as Collins grade III or IV and/or showed structural changes such as cysts or bone sclerosis, varus deformity or joint space narrowing at radiography. The uninjured knee was normal.

literature is included in Figure 1. At operation an acute osteochondral fracture of the medial tubercle was found in four knees with an associated osteochondral fracture of the latero-distal aspect of the medial femoral condyle in two knees. Presumably these small fractures are sustained by compression or cutting when the two surfaces mentioned contact each other during a sudden subluxation in the unstable knee.

In the three patients with rupture of both the anterior and posterior cruciate ligament and one of the collateral ligaments (group 3) osteophytes, structural bone changes and narrow joint space were shown at radiography. At operation large osteophytes together with widespread denudation of bone were found. In one of these patients the changes developed in the course of 2 years

(Figure 2) in another after 17 years. The third patient was a woman of 73 years with an osteoarthrotic varus deformity caused by 21 years of knee instability. The deformity was corrected by an osteotomy. Her other knee was completely normal (Figure 3).

DISCUSSION

Danielsson & Hernborg (1970) have shown that knee joints with osteophytes in the tibiofemoral joint do not necessarily develop structural changes. They do not mention drawer sign or collateral looseness, so one must expect that such patients were excluded from their study.

In studies on dogs after transection of the anterior cruciate ligament in one knee, Marshall (1969) and Marshall & Olsson (1971) found rapid osteophyte

Table 2 Radiographical findings Number of patients with unilateral abnormal findings

Type of cruciate ligament rupture	Duration of condition	No radiographic abnormalities	Osteophytes	Structural bone changes (cysts, sclerosis) and/or narrowing of joint space	Total no of patients
Anterior cruciate	½ to < 2 years	19	2		21
	2 to 3 years	5	7	1	12
	> 3 years	2	8	2	10
Posterior cruciate	1 and 5½ years	2	0	0	2
Both	2, 17 and 21 years	0	1	3	3
No of patients		28	20	6	48

Table 3 Grade of osteoarthritis according to Collins related to patients' age at injury to cruciate ligaments 0 = no cartilage destruction

Age (years)	No of patients	Patients divided according to Collins' grade of osteoarthritis				
		0	Grade I	Grade II	Grade III	Grade IV
< 20	12	6 (50 %)	1 (25 %)	3 (25 %)	0	0
20-30	30	14 (47 %)	6 (20 %)	8 (27 %)	2	0
31-40	3	0	2	0	0	1
> 40	3	1	0	0	0	2
Total	48	21	11	11	2	3

Among the 16 patients in group 1 with cartilage wear of grade I-III and up to 3 years since onset of the condition, meniscal damage, or previous meniscectomy, was found in eight, or half of them. In those with duration longer than 3 years, 7 out of 10 had meniscus injury or an earlier removed meniscus in combination with anterior cruciate ligament insufficiency. Five of these had cartilage wear grade II-III, two had none at all. Of the three patients with intact menisci, two had grade II cartilage wear and one had none. In group 3 all had osteoarthritis grade IV—one of them with intact menisci. The importance of this will be discussed.

In Table 2 the radiographical findings are shown, the same grouping of the patients being used. The radiographical signs progress at a somewhat slower rate

but in full accordance with the pathological anatomical changes.

Table 3 shows the grade of osteoarthritis related to the age at injury. No conclusions can be drawn from this, as nearly all the patients were below 30 at the onset of symptoms and the very few older patients (6) include the three with rupture of both cruciate ligaments and, in addition, the collateral ligaments and among these are two with very long lasting symptoms. They have all odds against them and have all developed a grade IV arthrosis.

A summary of the essential results is presented in Figure 1. This bar chart illustrates the increase in incidence and severity of osteoarthritis as the interval from the time of the original injury increases.

A finding not earlier described in the

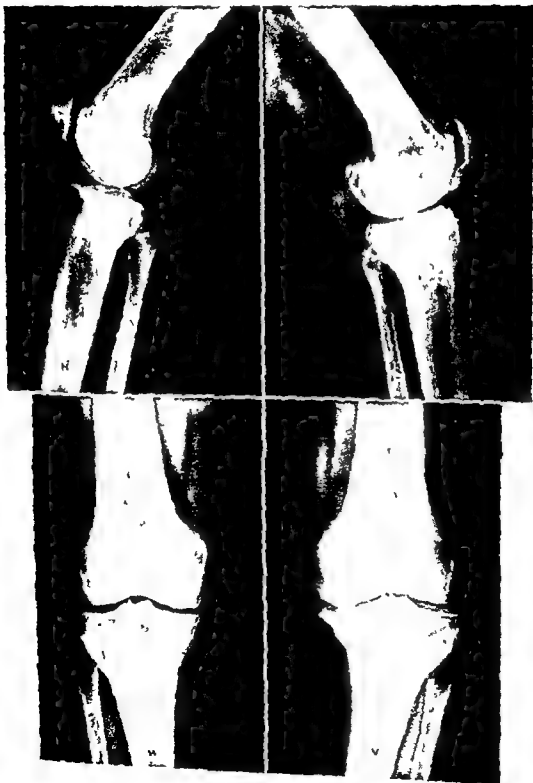




Figure 2 Photograph from the operation of a 49 year old man with total rupture of both cruciate ligaments and the medial collateral ligament. Duration of knee instability only 2 years. No destruction of articular cartilage which was found on all the articular surfaces of the joint. Here only the medial femoral condyle is visible. Note also the marked thickening of synovial membrane and fibrous joint capsule.

formation in the unstable knee, but no subchondral structural changes (cysts or bone sclerosis), even after longer observation periods. They conclude, as do Danielsson & Hernborg, that osteophytes are not necessarily a sign of degenerative lesions in the cartilage, and that the diagnosis of osteoarthritis should not be made solely on the presence of osteophytes.

From the results of these investigations it is not known whether the changes caused by unstable knees in the dog—and in man—are of a proliferative type only or if they are a precursor to, and may develop into, a significant osteoarthritis.

That many patients with unstable knees over the years develop an advanced osteoarthritis has been stressed by Liljedahl et al (1965). This is in accordance

with Collins' (1949) suggestion that the initial lesion of osteoarthritis is destruction of articular cartilage. Such destruction seems apt to develop as a consequence of repeated major and minor traumas caused by the numerous subluxations in unstable knees. Recently

Figure 3 Lateral and antero posterior radiographs of a 73 year old woman with an unstable left knee (V). The condition had been present for 21 years. At operation total atrophy of both cruciate ligaments and valgus instability was found. The right knee (H) was normal. Left knee with osteophytosis and bone sclerosis also in the femoro patellar joint. Loosened cartilage pieces have formed free bodies. Left femoro tibial joint with almost completely obliterated joint space, bone sclerosis and compression causing varus deformity.

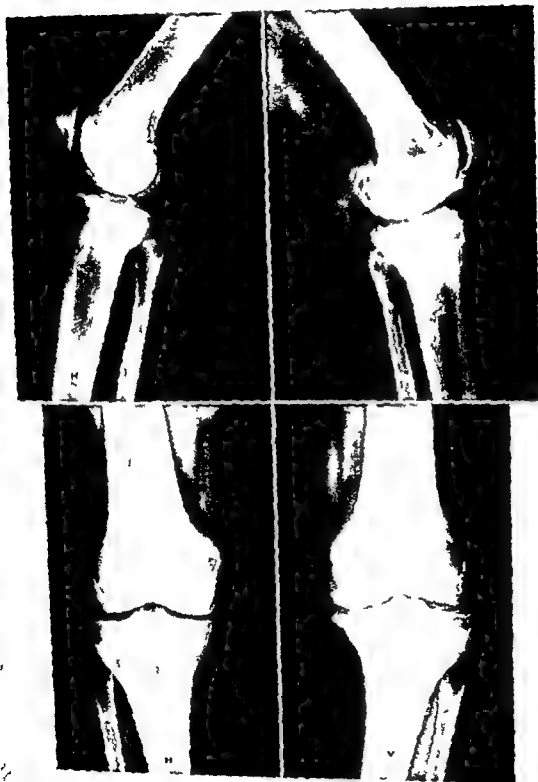




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THE HALLUX AND RHEUMATOID ARTHRITIS

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The purpose of this report is to consider involvement of the great toe by rheumatoid arthritis defining significant deformities describing clinical patterns and discussing the pathomechanics of these findings in what is an ongoing disease 200 consecutive patients admitted to hospital with classical or definite rheumatoid arthritis were screened for pain or deformity of the great toe Feet that had undergone previous surgery or had other underlying pathology were excluded from the series 194 feet were found to have hallucal involvement Although hallux valgus was the commonest deformity it was found in combination with other significant deformities in many cases Hallux rigidus was an important lesion in this series as was interphalangeal hyperextension Other important lesions encountered were metatarsus primus varus and medial rotation of the toe their relationship to hallux valgus is discussed

Key words: hallux valgus hallux rigidus, rheumatoid arthritis

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Foot disability in rheumatoid arthritis is common (Vainio 1936 Vidigal et al 1975), and frequently involves the hallux early in the disease Indeed symptoms in the first metatarso-phalangeal joint may precipitate local surgical intervention before the disorder's general nature is evident This may result in complaints by the patient that surgery caused the arthritis, aggravated foot problems or contributed nothing towards their relief This prompted an analysis of the significant hallucal deformities in a group of hospital patients with established rheumatoid arthritis This paper does not discuss the treatment of individual conditions of the great toe because every patient requires a different programme of manage-

ment The joints of the foot, knee and hip can dictate what sort of operation or conservative measure is necessary, not to mention the general medical state of the patient, so that any didactic statements about therapy would be misleading

PATIENTS AND METHODS

Consecutive admissions to the rheumatology and orthopaedic wards were assessed for foot pain and deformity in the presence of "classical" or definite rheumatoid arthritis (Ropes et al 1958) Out of 200 patients affected with the disease for more than a year (mean 12.9 years) significant findings involving the foot or

Bohr (1976) produced experimental osteoarthrosis in the rabbit knee joint by section of both cruciate ligaments and removal of the medial meniscus using the method of Hulth et al (1970). Within 10 months these animals developed changes in the joint cartilage and subchondral bone of the same severity as those found in advanced osteoarthrosis in man.

The findings in the present series are in good agreement with the experimental results mentioned above. If only one of the cruciate ligaments is ruptured many years may pass before significant osteoarthrotic changes develop even though progressive destruction of cartilage does occur over the years. In severe clinical injuries, however, with rupture of both cruciate ligaments—comparable to the experimental injuries produced in rabbits by Bohr (1976)—advanced osteoarthrotic changes do develop in a relatively short time.

The question of how a meniscus injury or meniscectomy may influence this course was investigated by Johnson et al (1974). They suggested that meniscectomy could cause osteoarthrosis over a period of many years. Unfortunately his material was not specific as cases of associated cruciate ligament rupture were fairly frequent. This is due to the fact that these injuries very often are combined as they were in the series presented above. In the present series, however, 10 patients with cartilage destruction of grade I to III and one patient of grade IV had intact menisci, which suggests that the meniscal factor is not essential, although it may be a contributory factor. This is also the opinion of Johnson et al (1974).

It may be concluded that osteophytes and pathoanatomical lesions of Collins' grade I and II are likely to develop within about 2 years in knees with anterior cruciate ligament rupture. Significant

arthrosis can develop after longer periods, especially in cases of rupture of both cruciate ligaments with gross instability. An additional meniscus lesion or removed meniscus may accelerate the process.

ACKNOWLEDGEMENTS

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REFERENCES

- Ahlbäck, S. (1968) Osteoarthrosis of the knee. A radiographic investigation. *Acta radiol* (Stockh.) Suppl. 277.
- Bohr, H. (1976) Experimental osteoarthrosis in the rabbit knee joint. *Acta orthop scand* 47, 559-565.
- Collins, D. H. (1949) *The pathology of articular and spinal diseases*. Arnold, London.
- Danielsson I. & Hernborg J. (1970) Clinical and roentgenologic study of knee joints with osteophytes. *Clin Orthop* 69, 302-312.
- Felsenreich F. (1934) Die Röntgendiagnose der veralteten Kreuzbandluxation des Kniegelenks. *Fortschr Röntgenstr* 49, 341-346.
- Hulth A. (1969) *Osteoarthritis. A survey of recent scientific research*. Thule International Symposia. Aging of connective and skeletal tissue, pp. 285-300. Nordiska Bokhandeln, Loflag, Stockholm.
- Hulth A., Lindberg I. & Telhag, H. (1970) Experimental osteoarthrosis in rabbits. *Acta orthop scand* 41, 522-530.
- Johnson R. J., Kettelkamp D. B., Clark W. & Leverson P. (1974) Factors affecting late results after meniscectomy. *J Bone Jt Surg* 56A, 719-729.
- Liljedahl S. O., Lindvall N. & Welterfors J. (1965) Early diagnosis and treatment of acute ruptures of the anterior cruciate ligament. *J Bone Jt Surg* 47A, 1503-1513.
- Magnusson P. B. (1941) Joint debridement. Surgical treatment of degenerative arthritis. *Surg Gynecol Obstet* 72, 1-9.
- Marshall J. I. (1969) Periarthrotic osteophytes. Initiation and formation in the knee of the dog. *Clin Orthop* 62, 37-47.
- Marshall J. I. & Olsson S. F. (1971) Instability of the knee. A long term experimental study in dogs. *J Bone Jt Surg* 53A, 1561-1570.

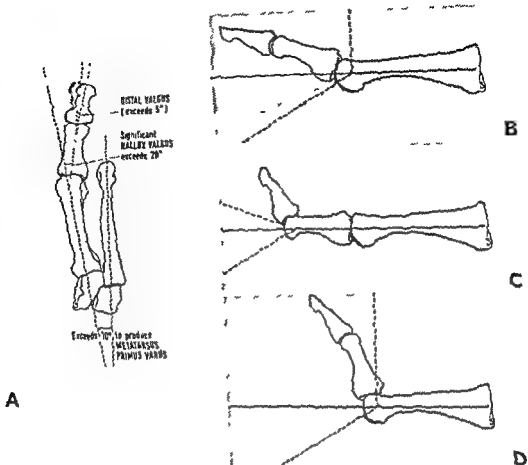


Figure 1 A Diagram to show the angular relationships measured on weight bearing radiographs of the foot

B Hallux rigidus—limited arc movement at the metatarsophalangeal joint. The maximum dorsiflexion as defined is 20° (unshaded arc) whereas the normal range is shown by the interrupted line. C Chisel toe—the distal phalanx maintains an extended posture having an arc of dorsiflexion beyond 20° (interrupted line) at the interphalangeal joint.

D Hallux elevatus—absent range of plantar flexion at the metatarsophalangeal joint.

Table 1 Summary of the 266 deformities that were found in 193 feet

Deformity	Bilateral	Unilateral	Total feet	Percentage of all the feet at risk
Hallux valgus	42	30	114	59
Hallux rigidus	24	7	55	28
Chisel toe	12	19	43	22
Hallux elevatus	6	8	20	11
Interphalangeal claw	3	7	13	7
Interphalangeal valgus	4	5	13	7
Interphalangeal fusion	1	2	4	2
Metatarsophalangeal dislocation	1	1	3	< 2
Hallux varus	0	1	1	< 1
No measured deformity	7	16	30	15

tory or neurological deficit, the presence of swelling, callosities, bursae, sinuses, nail changes, and the state of footwear were made. With the patient supine and knee extended, angular relationships between the first metatarsal bone and phalanges were measured with a goniometer, similarly passive movements of the joints were estimated. Ideally observations should be made standing on a firm surface, in practice this is difficult and the supine examination was a compromise. In this position active movement cannot achieve the functional range possible when erect, thus passive estimations were necessary: for example, the normal hallux dorsiflexes to 90° or more when the phalanges are subjected to body-weight, yet supine active contraction may achieve only 60° or less.

Radiographs and photos of the standing forefoot display halluxal deformities most clearly and are essential for measuring metatarsus primus varus accurately. Patients with valgus or varus hindfoot, or those who were unable to stand barefoot could not be recorded in this way. The relationship of the first metatarsal, the sesamoids and the remaining metatarsal heads was demonstrated in tangential partial weight bearing radiographs (Dixon & Gheith 1973).

DEFORMITIES

The major deformities, as defined below, were hallux valgus (Figure 1a), hallux rigidus (Figure 1b), and "Chisel-toe" (Figure 1c). Less common and less disabling deformities were hallux elevatus (Figure 1d), interphalangeal claw toe, interphalangeal valgus (Figure 1a), interphalangeal fusion, hallux varus, and metatarsophalangeal dislocation (Table 1).

Of 104 patients examined, four had undergone bilateral and four unilateral surgery of the hallux. Rejection of these, and a further foot subjected to ankle fusion and one affected by *pohomyelitis* left 100 patients with 194 feet for analysis. Bilateral deformity was recorded in 70 patients and unilateral deformity in 23. If one recalls the 12 feet excluded by previous surgery, we conclude that over 50 per cent of patients with rheumatoid arthritis may suffer from foot disability and of these approximately 90 per cent will manifest significant great toe deformity in one or both feet.

Hallux valgus

Deformity was considered significant when the proximal phalanx deviated laterally on the metatarsal at least 21° as measured by standing radiographs or photographs (Figure 1a), and involved 114 feet of which 99 exhibited a 'bunion' as indicated by skin pressure signs of reddening and thickening, bursid formation with underlying bony hypertrophy characteristic of non-rheumatoid hallux valgus was unusual. Six feet with hallux valgus of 20° or less also displayed 'bunion' formation whilst 15 feet with hallux valgus between 21° and 50° did not, being patients who walked little, wore soft slippers or individually cast seamless shoes. This would suggest that bunion formation is a function of tight footwear rather than the extent of deviation. Four feet with mild to moderate hallux valgus (15°, 19°, 25° and 38°) exhibited septic 'bunions' with sinuses suggesting that patients with more severe deviation had learned how to select more suitable footwear.

Radiographic evidence of erosions and irregularity of the first metatarsophalangeal joint were noted in 98 (86 per cent) of the 114 feet with hallux valgus (Table 2). Of the toes without X-ray change, valgus varied from 25° to 63°.

Metatarsus primus varus

Divergence between the long axes of the first and second metatarsal of 10° or more (Figure 1a) is a well recognised association with hallux valgus of non-rheumatoid origin and we confirmed a similar association in rheumatoid patients with angles between 10° and 25° in 89 out of 100 feet with suitable radiographs. Significant metatarsus primus varus was observed in a few feet with hallux valgus of less than 20° but increasing severity of valgus was generally correlated with increasing metatarsal deviation (Figure 2). Of 47 toes with valgus exceeding 40°.

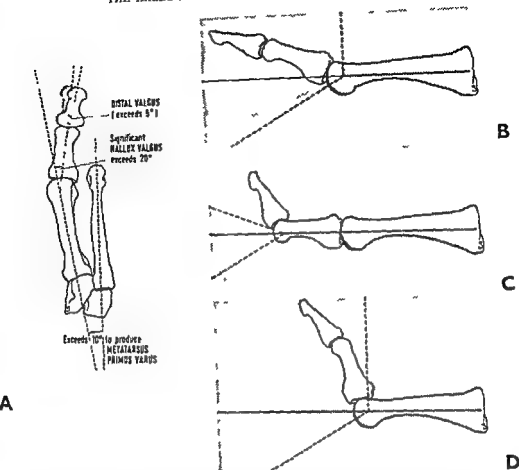


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Metatarsophalangeal dislocation	1	1	3	< 2
Hallux varus	0	1	1	< 1
No measured deformity	7	16	30	15

Table 2 Summary of the radiological findings in 194 feet

Target Joint	Proximal changes on X-ray	
	Present	Absent
Interphalangeal joint	57	137
Interphalangeal deformity	29	40
Chisel toe	20	23
Interphalangeal valgus	8	5
Interphalangeal claw	1	12
Interphalangeal fusion	4	11
No interphalangeal deformity	28	97
Metatarsophalangeal joint	145	49
Metatarsophalangeal deformity	126	27
Hallux valgus	98	16
Hallux rigidus	45	10
Hallux elevatus	17	3
Hallux varus	1	0
No metatarsophalangeal deform	19	22
First metatarso medial cuneiform joint	44	144
Hallux valgus	30	84
Metatarsus primus varus $> 10^\circ$	30	70
Interphalangeal and metatarso phalangeal joints combined	42	15
First metatarso medial cuneiform joint and metatarso phalangeal joint combined	39	5
Interphalangeal metatarso phalangeal and first metatarso medial cuneiform joints combined	13	31
Ankle and/or tarsal changes	121	73

metatarsus primus varus was 10° or more in every case. It is debatable whether metatarsal deviation initiates hallux valgus or is a compensatory sequel to subluxation of the proximal phalanx, nevertheless if the first metatarsal deviates excessively from the second then structural changes at their bases are inevitable. In this series radiographic erosions, sclerosis or fusions affecting the first metatarso-medial cuneiform joint, the interval between the first and second metatarsal bases or between medial and intermediate cuneiforms were observed (Table 2) in 44 feet and compared where possible with the angle of metatarsus primus varus. The latter was significantly greater in those feet with radiographic disease of the metatarsal base than those without ($P < 0.01$), the mean angles of metatarsus primus varus being 15.5° and 12.7° respectively, denoting that basal disease, if not the primary cause, at least contributes to the more severe degrees of metatarsal deviation and hence hallux valgus itself.

Hallux tortus

Medial twisting or rotation of the phalanges about the first metatarsal long axis has received little attention although Hardy & Clapham (1951) recognised its

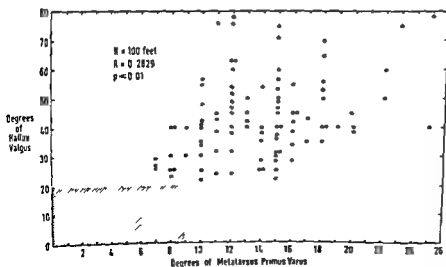


Figure 2 Graph showing the angle of hallux valgus plotted against the angle of metatarsus primus varus. The correlation is significant ($P < 0.01$).
 N = Number of X rays
 R = Correlation coefficient



Figure 3 *Hallux tortus* Medial rotation of the hallux in the presence of valgus deformity

be significant although lesser degrees of rotation were uncommon without accompanying hallux valgus. Hallux tortus of more than 20° was always associated with hallux valgus (Figure 4). Not all valgus toes were twisted but of 42 toes with more than 40° hallux valgus, 36 (86 per cent) were rotated from 20° to 65° , many of which developed a characteristic callosity medial to the interphalangeal

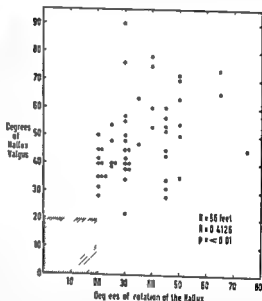


Figure 4 Graph showing the angle of hallux valgus plotted against the rotational angle of tortus. There is a positive correlation which is significant ($P < 0.01$). N = Number of feet measured R = Correlation coefficient

singular association with hallux valgus, however, they reported no accurate measurements to quantify the rotational displacement. In our patients, standing photographs taken of the toes end on have been utilised to measure the angle made by the great-toe nail margin with respect to the plane of the floor (Figure 3), the nail normally being parallel to the floor. This angle was estimated to the nearest 5° and angles of 20° and above taken to

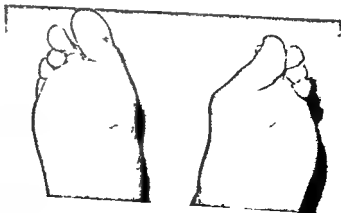


Figure 5 *Hallux tortus* Plantar callosities are present under the medial aspect of the interphalangeal joint

joint (Figure 5) a source of complaint in addition to their "bunion". Significant rotation was bilateral in 23 patients. In two the twist was reversed or lateral, one being a case of hallux varus and one of hallux elevatus. Lateral tortus was also recorded in another case of hallux varus, a sequel to excision arthroplasty for hallux valgus.

Hallux rigidus

Terminology with respect to mobility of the first metatarso-phalangeal joint is confusing for by definition rigidus implies complete fixity, nevertheless, this quality applies to those rheumatoid joints achieving bony fusion following severe and prolonged disease. However, in current practice hallux rigidus encompasses mobile yet restricted joints (Mercer & Duthie 1964) with absence or reduction of dorsiflexion as the essential indicator of disability. Bonney & Macnab (1952) emphasise that restriction of movement may not correlate with disability for this varies with age, sex, footwear, occupation, etc., and on interphalangeal joint mobility. In rheumatoid arthritis, we would add, hallucal function is also related to tarsal and ankle joint disease, for restriction of hindfoot dorsiflexion stresses a damaged great-toe during walking, and such stress increases as metatarso-phalangeal mobility diminishes. Vainio (1956) noted distal phalangeal hyperextension with associated callosities beneath the interphalangeal joint in rheumatoid patients when dorsiflexion of the proximal phalanx was 20° or less. Our experience demonstrates this to be far from universal and shows callosities present in many feet for other reasons, we do, however, accept Vainio's definition of hallux rigidus as 20° or less of passive dorsiflexion of the proximal phalanx on the first metatarsal. Vainio makes no comment on the plantar-flexion range and in noting general lack of attention to this Kessel & Bonney (1958), when dis-

cussing adolescent hallux rigidus, state that a good range of plantar-flexion was preserved in all their cases with an average of 50° ; the average dorsiflexion being only 5° . In our series, where dorsiflexion was 20° or less, a range of plantar-flexion was obtained in all but two cases such patients are considered to have hallux rigidus (mobile) in contradistinction to a smaller group of patients with truly rigid or fused joints termed hallux rigidus (immobile). This terminology may appear tendentious but as demonstrated below the two groups differ in several respects.

Hallux rigidus (mobile) Forty-three feet of 30 patients came into this category, 26 feet displayed an accompanying hallux valgus, 28 feet showed radiological evidence of tarsal and/or ankle changes and 23 feet (53 per cent) developed hyperextension of the distal phalanx. Some cases of hallux rigidus displayed minimal or no radiological evidence of erosions in the metatarso-phalangeal joint and some possibly developed restricted movement before the onset of rheumatoid arthritis. Furthermore, some patients stated that their toes were stiff prior to and independent of the arthritis. However, in long-standing severe rheumatoid arthritis there is little doubt that the disease itself precipitates the ultimate complication of spontaneous joint fusion.

Hallux rigidus (immobile) The 12 feet in this group illustrate this latter statement for the mean duration of rheumatoid disease was 25.2 years against 12.1 years in the hallux rigidus (mobile) group. In addition, every foot demonstrated not only tarsal but ankle changes including several spontaneous fusions of these joints. These findings suggest that severe and prolonged disease were necessary prelude to metatarso-phalangeal joint fusion. A position of hallux valgus was present in 7 of the 12 feet, a similar proportion to the mobile group. Co-existent distal hyperextension was present in five feet, again much as in the mobile

group and thus one concludes that rheumatoid hallux rigidus is compensated by distal phalangeal hyperextension in approximately half the cases, less than might be anticipated. In the non rheumatoid foot Fitzgerald (1969) has shown that after metatarso-phalangeal arthrodesis compensatory interphalangeal dorsiflexion does not occur and indeed mobility decreases as a sequel to the altered loading on the distal joint and intra-articular degenerative changes were accelerated. Six feet showed evidence of erosions at the first metatarsal medial cuneiform joint.

Hallux flexus

Vamio (1956) considers this to be an extreme form of hallux rigidus where dorsiflexion is totally absent and the proximal phalanx is held plantar flexed. Weight is not taken by the metatarsal head and instead is transferred to the distal phalanx resulting in callosities on its plantar surface. In conventional foot

wear, however, the major symptom of pain follows friction between the shoe 'upper' and the dorsum of the metatarsal head exposed by the flexed phalangeal attitude.

In this series no toes were classified as hallux flexus, perhaps an indicator of its infrequency, although elsewhere we have observed this deformity in rheumatoid feet (Figure 6).

Chisel toe

Interphalangeal hyperextension alone or in association with hallux rigidus can be itself a source of symptoms particularly when dorsal subluxation of the distal on the proximal phalanx ensues. The "chisel toe syndrome" (Dixon 1971) is characterised by callosity formation on the plantar aspect (Figure 7a) and a skin furrow on the dorsal aspect of the interphalangeal joint associated with changes at the free nail margin resulting from collision between it and the overlying shoe (Figure 7b). Increasing hyperexten-

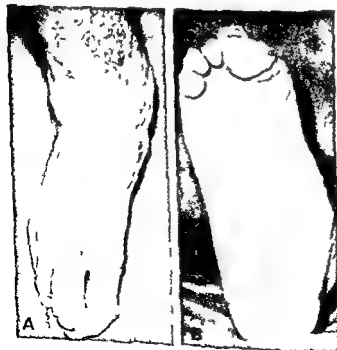


Figure 6 Hallux flexus

A Dorsal view showing callosity over the metatarso phalangeal joint

B Plantar view showing callosity under the pulp of the great toe

sion augments the probability of the nail cutting or chiselling through the shoe, hence the name. In other cases the thickened nail may damage the pulp leading to infection (Figure 7c).

Excess joint hyperextension is defined as dorsiflexion of 20° or more of the distal phalanx (Figure 1c), which in this series was noted in 83 feet, of which 43, involving 31 patients, were considered to be "chisel toes".

As few as 20 out of 43 "chisel toes" were found to have radiographic changes in the interphalangeal joint, namely erosions and juxta-articular cyst formation (Table 2) thus some 53 per cent of "chisel toes" have dorsal subluxation of the distal phalanx without significant joint damage (Figure 7d). Likewise, 32

out of 40 toes with simple hyperextension deformity lacked associated bone changes, indicating that subluxation is frequently related to factors other than interphalangeal joint destruction.

As has been suggested, hyperextension of the distal joint may compensate for hallux rigidus and indeed 14 "chisel toes" were so associated, however, this is only 25 per cent of the rigid halluces. Surprisingly, we found an association with hallux elevatus, there being five "chisel toes" among 20 feet with elevatus. Eight unilateral "chisel toes" displayed no demonstrable hyper-extension in the opposite toe whilst 20 were combined with hallux valgus (25° to 55°), somewhat fewer than expected and proportionately less than those associated with rigidus.

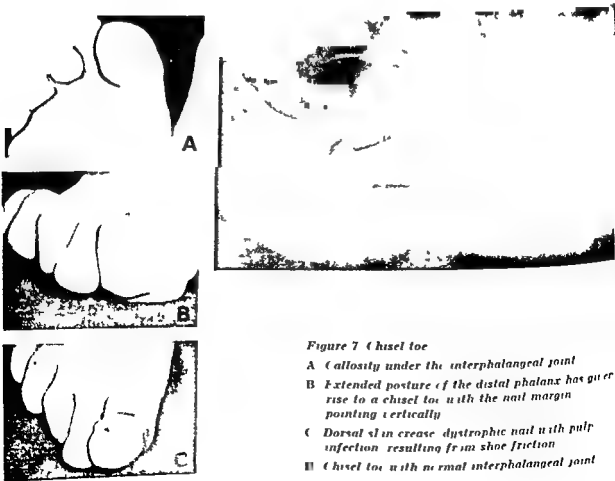


Figure 7 Chisel toe

- A Callosity under the interphalangeal joint
- B Extended posture of the distal phalanx has given rise to a chisel toe with the nail margin pointing vertically
- C Dorsal skin crease dystrophic nail with pulp infection resulting from shoe friction
- D Chisel toe with normal interphalangeal joint

Figure 8 *Hallux elevatus and valgus*

- A Anterior view showing marked elevatus with packing of the lesser toes
 B Dorsal view showing severe valgus
 C Plantar view showing complete absence of the hallux from the plantar profile



A



B



C

OTHER DEFORMITIES

Hallux elevatus

Elevatus is defined as inability to plantar-flex the proximal phalanx beyond neutral in the presence of dorsiflexion exceeding 20° (Figure 1d). In most instances dorsiflexion was 60° – 90° , frequently the loss of plantar-flexion was severe with inability to achieve neutral by as much as 40° resulting in striking elevation of the proximal phalanx (Figure 8). As a consequence compensatory plantar-flexion of the distal phalanx might be expected with fixed interphalangeal clawing and dorsal callosity formation over the interphalangeal joint. However, out of 20 feet with hallux elevatus, only two toes were clawed at the distal joint, by contrast 15 interphalangeal joints were hyperextensible beyond 20° . Other co-existent problems included 12 feet with ankle or tarsal joint damage and 11 feet with hallux valgus both these numbers were in proportion to the overall distribution. By our definition hallux rigidus cannot co-exist with elevatus.

Elevation of the proximal phalanx is said to compensate for depression of the metatarsal head which may be congenital or possibly in rheumatoid arthritis a sequel to bone destruction at the metatarsocuneiform level. The five feet with erosions at the metatarsal base were insufficient to support this possible mechanism. Radiologically rheumatoid damage of the metatarsophalangeal joint was recorded in 18 (90 per cent) of these feet, the interphalangeal joint was similarly affected in only three (15 per cent).

Hallux elevatus rarely caused com-

plaint of itself for associated and more symptomatic deformities were commonly present (Table 3)

sion augments the probability of the nail cutting or chiselling through the shoe, hence the name. In other cases the thickened nail may damage the pulp leading to infection (Figure 7c).

Excess joint hyperextension is defined as dorsiflexion of 20° or more of the distal phalanx (Figure 1c), which in this series was noted in 83 feet, of which 43, involving 31 patients, were considered to be "chisel toes".

As few as 20 out of 43 "chisel toes" were found to have radiographic changes in the interphalangeal joint, namely erosions and juxta-articular cyst formation (Table 2); thus some 53 per cent of "chisel toes" have dorsal subluxation of the distal phalanx without significant joint damage (Figure 7d). Likewise, 32

out of 40 toes with simple hyperextension deformity lacked associated bone changes, indicating that subluxation is frequently related to factors other than interphalangeal joint destruction.

As has been suggested, hyperextension of the distal joint may compensate for hallux rigidus and indeed 14 "chisel toes" were so associated, however, this is only 25 per cent of the rigid halluces. Surprisingly, we found an association with hallux elevatus, there being five "chisel toes" among 20 feet with elevatus. Eight unilateral "chisel toes" displayed no demonstrable hyper-extension in the opposite toe whilst 20 were combined with hallux valgus (25° to 55°), somewhat fewer than expected and proportionately less than those associated with rigidus.

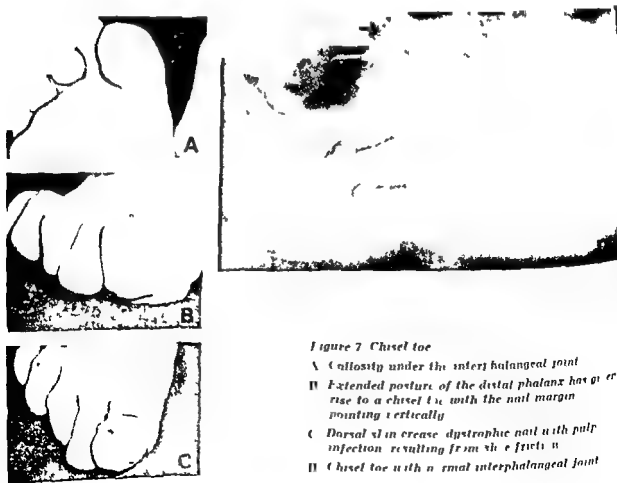


Figure 7 Chisel toe

- A Callosity under the interphalangeal joint
- B Extended posture of the distal phalanx has given rise to a chisel toe with the nail margin pointing vertically
- C Dorsal view crease dystrophic nail with pulp infection resulting from the fracture
- D Chisel toe with normal interphalangeal joint

the common dislocation of the lesser toes onto the dorsum of metatarsal heads or necks



Figure 9 Metatarsophalangeal dislocation. The sesamoid bones have maintained a normal anatomical relationship to the proximal phalanx

Hallux varus

Deviation of the proximal phalanx medially from the metatarsal mid line axis is relatively rare and even small degrees of varus are worthy of note. Of the two cases with this deformity, one deviated 20° and the other a sequel to a Sellers arthroplasty, some 25° . As observed under hallux tortus both were associated with lateral rotational changes of the order of 15° and 10° , respectively. In the toe not subjected to surgery cystic change



Figure 10 Hallux varus showing a cyst or geode near the medial edge of the metatarsophalangeal joint

was well marked in the base of the proximal phalanx at its medial corner suggesting that the varus position was a protective response to relieve pressure opposite the cyst (Figure 10). Lateral phalangeal rotation with hallux varus is the reverse of medial rotation commonly accompanying hallux valgus.

COMBINED DEFORMITIES

Of 194 feet at risk, 31 displayed no significant hallux deformity whilst the remaining 163 feet yielded a total of 266 deformities exclusive of metatarsus primus varus, hallux tortus, and interphalangeal hyperextension. Thus many feet manifested two deformities and indeed three were demonstrated in 15 feet, the ubiquitous hallux valgus being present in all of this latter group (Table 4).

Hallux valgus was observed in 60 per cent of the total feet, being noted in a similar percentage of feet with rigidus and elevatus. However, hallux valgus was seen in combination with only 47 per cent of chisel toes and most strikingly only 8 per cent of interphalangeal valgus. By contrast hallux valgus complicated 92 per cent of interphalangeal claw toes (Table 5).

Hallux rigidus involved 28 per cent of the total feet and affected a similar percentage of valgus and "chisel toes". Only one case of rigidus was combined with interphalangeal clawing and none were

Table 4 Triple deformities of the hallux

Associated deformities	Number of feet involved
Valgus + rigidus + chisel toe	6
Valgus + rigidus + interphal valgus	2
Valgus + elevatus + chisel toe	2
Valgus + elevatus + interphal claw	2
Valgus + rigidus + interphal claw	1
Valgus + chisel toe + interphal fusion	1

Table 3 Deformities associated with hallux elevatus

Deformity	Feet affected	Feet at risk	Association with hallux elevatus %
Isolated hallux elevatus	6	20	30
Hallux valgus with hallux elevatus	11	114	10
Chisel toe with hallux elevatus	5	43	12
Interphalangeal claw with hallux elevatus	2	13	15
Interphalangeal hyperextension with hallux elevatus	15	83	18

Interphalangeal claw

Inability of the distal phalanx to be dorsiflexed on the proximal with assumption of a flexed attitude between 10° and 30° was defined as clawing and affected 13 toes, six of these developed a symptomatic dorsal callosity over the interphalangeal joint. No less than 12 cases were combined with hallux valgus, however, the thirteenth was accompanied by 20° of medial tortus, a metatarsal head "bunion" and 12° of hallux valgus. Thus a strong association with hallux valgus and tortus is established. In addition, interphalangeal joint erosion and destruction was absent in 12 of the 13 cases, suggesting that rheumatoid disease at this level is an unimportant factor in the aetiology of this deformity. No attrition ruptures of extensor hallucis longus were seen and no significant neurological deficit demonstrated.

Interphalangeal valgus

Valgus deviation of the distal on proximal phalanx of more than 5° , measured by standing radiographs (Figure 1a), was observed in 13 feet achieving a maximum of 30° in two feet. Callosities of the "bunion" type were present on the medial aspect of this joint in three cases causing minor discomfort, and in five other cases concurrent "chisel toe" was a complicating factor. Curiously, accompanying hallux valgus was significant in one foot only. Erosive and destructive changes seen in the interphalangeal joint of eight

halluces indicate the importance of articular damage in establishing joint instability and hence deformity.

Interphalangeal fusion

Four toes fused spontaneously at the distal joint in the presence of disease of long duration and extensive radiological damage in the metatarso-phalangeal tarsal and ankle joints of all cases. Hallux rigidus, including two metatarso-phalangeal joint fusions, was observed in all four and severe concurrent hallux valgus in three cases. One joint fused in 25° of dorsiflexion and the remainder in the neutral position. One first ray fused at the distal, proximal and basal metatarsal joints in addition to which the tarsus and ankle had fused creating a bony continuity from the distal phalanx to the proximal tibia thus eliminating functional mobility in the leg below the knee joint.

Dislocated first metatarso-phalangeal joint

Complete joint dislocation is rare in contrast to subluxation, whether valgus tortus or elevatus. Three dislocated great toes were seen, all of which were displaced laterally between the first and second metatarsal heads, the proximal phalanx taking the sesamoids with it (Figure 9) and all ankylosed or fused in the dislocated position despite co-existing valgus and tortus deviation. No dorsal displacement was observed in contrast to

However, in this disease deformities are often multiple and complex, extremely painful and crippling and commonly influenced by joint changes elsewhere in the foot and more proximally. When present pre-existing problems are aggravated by the disease and as a corollary these problems may determine the ultimate direction and type of rheumatoid deformity, e.g., the mobile flat foot becomes a stiff extremely valgus foot, or the hallux rigidus becomes more rigid and precipitates a 'chisel toe'.

Terminology

In the English literature, this subject is muddled in several ways particularly by confusion between anatomical terms and clinical descriptions. The former utilising the median limb axis and the latter

the median body axis as reference lines (Figure 11). Thus one arrives at the ambiguous proposition that relative overaction of the adductor hallucis muscle is a factor causing or aggravating hallux valgus, whereas adduction indicates medial and valgus indicates lateral deviation. Whilst the application of the median limb axis with pre- and post-axial margins to compare the human foot with other species is of considerable phylogenetic interest, it is irrelevant to patients who are not quadrupeds. Furthermore, one foot cannot function normally without its complementary fellow and therefore the mid line between weight bearing feet, that is the median body axis, is a logical reference line. Acceptance of this axis would necessitate revision of adductor hallucis as abductor hallucis and vice versa.

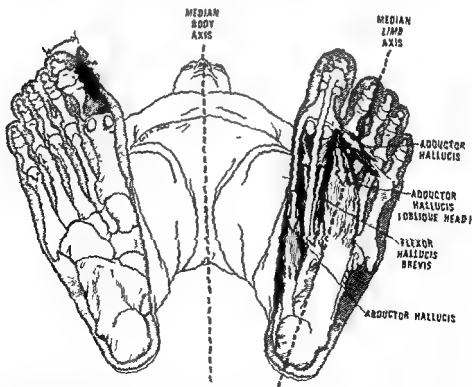


Figure 11 Diagram to show the inappropriate nomenclature of the so called adductors and abductors of the hallux with reference to the median body axis and the median limb axis.

Table 5 Deformities associated with hallux valgus

Deformity	Feet affected	Feet at risk	Association with hallux valgus %
Isolated valgus	47	114	41
Rigidus with valgus	33	55	60
Chisel toe with valgus	20	43	47
Elevatus with valgus	11	20	55
Interphalangeal claw with valgus	12	13	92
Interphalangeal valgus with hallux valgus	1	13	8

Table 6 Deformities associated with hallux rigidus. The mobile and immobile types are combined

Deformity	Feet affected	Feet at risk	Association with rigidus %
Isolated hallux rigidus	14	55	25
Hallux valgus with hallux rigidus	33	114	29
Chisel toe with hallux rigidus	14	43	33
Interphalangeal claw with hallux rigidus	1	13	8
Interphalangeal valgus with hallux rigidus	0	13	0

Table 7 Deformities associated with chisel toe

Deformity	Feet affected	Feet at risk	Association with chisel toe %
Isolated chisel toe	8	43	19
Hallux valgus with chisel toe	20	114	18
Hallux rigidus with chisel toe	14	55	25
Hallux elevatus with chisel toe	5	20	25
Interphalangeal valgus with chisel toe	6	13	38

seen with interphalangeal valgus (Table 6)

"Chisel toes" were observed in 22 per cent of the feet at risk and complicated a similar percentage of valgus, rigidus and elevatus groups, its association with interphalangeal valgus was 38 per cent (Table 7)

DISCUSSION

To some observers the foregoing analysis may complicate what appear mundane problems of hallux valgus, hallux rigidus or bunions, often diminished by more important co-existent disabilities. This is

not our objective for we believe detailed consideration assists clarification and interpretation of the patient's symptoms promoting a rational approach to management, particularly operative treatment. Despite the protean nature of rheumatoid arthritis, undoubted patterns of incapacity and deformity are found suggesting causal factors which are helpful in prognostication.

Clearly these deformities are not specific to rheumatoid arthritis for similar if less disabling changes result from congenital, developmental, traumatic, metabolic and degenerative causes, moreover, one cannot assume absence of deformity prior to the onset of rheumatoid arthritis.

curtails markedly any remaining propulsive capacity in the hallux

If there is a valgus attitude, and a large proportion of rheumatoid feet are so aligned the weight is concentrated towards the medial foot margin and hence plantar and medial aspects of the hallux. In contrast the varus attitude produces abnormal loading of the lateral foot margin and elevation of the first metatarsal, which may fail to make ground contact causing compensatory plantar flexion of the hallux and occasionally hallux flexus deformity

Thus the type and degree of great toe deformity can be determined by the attitude of the foot, which is dependent on pathology in the proximal joints of tarsus and ankle and which in turn may reflect changes yet more proximally, as for example, when genu valgum aggravates pes valgus, and external rotational hip contracture alters the attitude of the foot

In summary, the factors contributing to great toe symptoms and deformity in the walking patient are primarily pre-existing deformity, the activity and extent of rheumatoid changes in the hallucal joints, ground friction and shoe friction. These are modified by body weight, heel height, the foot attitude determined by proximal disease and the lesser toe disposition. More remote factors are the presence of oedema, ischaemia, anaesthesia, poor muscular control, walking incapacity, upper limb inability to control sticks and crutches, the presence of other diseases and probably drug therapy, e.g., steroids and analgesics

Pathological and clinical considerations

Early disease results in synovial swelling and joint effusions unassociated with measurable deformity of the hallux as defined above, but nevertheless associated with acute symptoms as unyielding shoes precipitate containment friction and pressure. If synovial infiltration is temporary in nature, minimal or no per-

manent bone or joint changes follow. Persistent swelling, however, produces stretching of ligaments and joint capsules, and more chronic disease may invade cartilage and bone causing structural joint damage with resultant stiffness and deviation. If ligamentous laxity or stretching is the main feature, then deformity may still arise and indeed ultimately be severe due to the influence of weight-bearing and footwear. In many feet articular structural damage and ligamentous laxity coexist.

We postulate articular damage leads to ankylosis and ultimately induces fusion at the metatarsal base, rigidus and fusion at the metatarsal head and occasionally valgus but rarely fusion at the interphalangeal joint. Likewise ligamentous laxity with minimal cartilaginous destruction provokes varus of the metatarsal, valgus of the proximal phalanx and hyperextension of the distal phalanx. Therefore concurrent ankylosis and joint laxity produce combined hallux valgus with hallux rigidus, or hallux rigidus with 'chisel toe', or hallux valgus with hallux rigidus and 'chisel toe'.

It is of interest to compare the behaviour of the first with the lesser metatarsophalangeal joints. 1) Whilst the lesser toes on occasion sublux laterally and in the case of the little toe medially, the pattern of dorsal subluxation leading to dorsal dislocation is common and usually symmetrical, contrasting with the uncertainty of hallucal behaviour which is often strikingly divergent between right and left great toes. 2) The common dislocation of the lesser toes contrasts with its rarity in the hallux. 3) Whilst fusion of the first metatarsophalangeal joint is not common it is extremely rare in the lesser metatarsophalangeal joints. 4) The second to fifth toes commonly develop claw and hammer deformities whilst this is seldom seen in the hallux. 5) Barefoot contact between the lesser toes and the ground is frequently lost

Clinical terminology itself is not without inexactitude as mentioned earlier, hallux rigidus is commonly correlated with limited mobility rather than its literal meaning of complete rigidity, and hallux valgus denotes deviation in one plane despite displacement in the first ray being three dimensional. Moreover, these descriptions indicate one component only of the disordered anatomy and do not explain the actual aetiology, e.g. rheumatoid disease, or even suggest the joint pathology, e.g. arthritis or subluxation. One cannot easily discard the time-honoured phrase 'hallux valgus' despite its limitations and as a consequence there is a need for the terms 'elevatus' and 'flexus' to describe deformities which are often co-existent with hallux valgus or varus and yet in a plane at 90° from them. If one accepts the precision of these terms, it is reasonable to denote any accompanying rotational deformity. It is appropriate to use Latin terminology and we have suggested 'tortus' as the equivalent of 'twisted' without, however, indicating the direction of twist. In a particular case a full description might be 'hallux valgus, elevatus et tortus'. This precise if somewhat pedantic formula also hints at particular instability of the first metatarso-phalangeal joint suggesting to us the less precise yet accurate and possibly more acceptable 'hallux subluxatus'. Alternatively in rheumatoid arthritis it is appropriate to say 'rheumatoid hallux' as indicative of a disease understood to cause complex deformity of all the joints of the first ray.

Functional consideration

Whilst the great toe is not so versatile as the thumb, its contribution to foot function is as vital as the thumb is to the hand. Analogies of structure between the two digits are obvious and it has been and remains tempting to emphasise similarity of function based on structural resemblance.

As Wood Jones (1944) maintains the foot is a specialised organ permitting man's erect posture and is in no way an imperfect hand.

Fundamentally, the great toe functions on terra firma, firstly to support body weight and assist balance, secondly to initiate propulsion by virtue of the powerful muscles attached to it. During walking the traction exerted by the forefoot requires friction between plantar surface and the sole of the shoe, and between shoe and the unyielding ground. In a temperate climate the shoe protects and necessarily encloses the foot submitting the hallux to additional medial and dorsal friction dependent on the rigidity and tightness of the shoe and the spread of the lorded foot. These two sources of friction, one inevitable and consequent on the erect posture under the influence of gravity and the other avoidable and dependent on footwear selection, must be clearly distinguished.

The dynamic gait of normal walking requires movement of all foot joints including those of the hallux which consequently must take weight. The actual range of movement will depend on stride length and gait speed. In contrast, the disabled rheumatoid patient tends to use a 'static' gait because pain and joint disorganisation diminish and prevent movement accentuating the passive supportive role of the foot. In this situation the hallux is a forward extension of the foot platform, in which it may be isolated for the lesser toes are frequently subluxated or dislocated and thus not in contact with the ground. The actual degree of contact varies with heel height. Thus if the ankle is sufficiently plantar-flexed by raising the heel the subluxated toes become weight-bearing with the penalty of increased thrust on the forefoot and painful shoe containment, in addition to sustaining the upward pressure from the ground. In practice the patient discovers a low heel is more comfortable though it

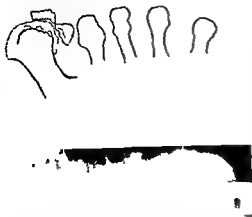


Figure 10 Tangential X ray of the metatarsal heads in a patient with rheumatoid hallux valgus. The first web space is abnormally wide and the eroded sesamoid bones are dislocated between the first and second metatarsal heads.

Valgus may arrest at any stage, for example when joint destruction introduces concomitant rigidity with ankylosis, or the second and lesser toes are resistant to disease and maintain a lateral buttress. Valgus may diminish after dislocation ensues although the metatarsal head becomes more prominent (Figure 9). We believe that selection of suitable shoes will arrest hallux valgus in some feet.

Chisel toe: At surgical exploration we have failed to demonstrate attrition rupture of flexor hallucis longus in this syndrome. Possibly hyperextension of the distal joint is related to congenital ligamentous laxity, which is common enough in the general population, and aggravated by rheumatoid arthritis and by steroid therapy in some cases. Others develop compensatory distal hyperextension in the presence of hallux rigidus.

Hallux elevatus: More puzzling is the association of hyperextension of the proximal and of the distal phalanx in 15 (75 per cent) cases of hallux elevatus. We surmise the primary lesion is due to metatarsophalangeal damage which in-

duces a protective posture in dorsiflexion enabling extensor hallucis longus to secure mechanical advantage, establishing a vicious circle of muscle imbalance on both this and the interphalangeal joint. The latter being generally free of disease readily adopts a hyperextended position and any attempt to flex it inevitably tends to flex the damaged proximal joint, causing pain and protective extensor spasm leading finally to persistent hallux elevatus.

Interphalangeal claw: To account for the mechanism of clawing, explanation of its association with severe hallux valgus and tortus accompanied by any undamaged interphalangeal joint is required. We suggest muscle imbalance at the interphalangeal joint develops in favour of flexor hallucis longus as a sequel to dislocation of the sesamoids and subluxation of the proximal phalanx laterally, compounded by medial rotation of the toe. The rotation hinders effective weight bearing by the distal phalanx ensuring unhampered action of flexor hallucis longus and consequent clawing in what is virtually a valgus attitude promoted by dislocation of the second toes and no doubt ill fitting footwear. Clawing is not uncommon in the general population, frequently being accompanied by depression of the metatarsal head and compensatory hyperextension of the proximal phalanx. Such a basis might account for the two feet deformed by elevatus additional to valgus and clawing.

Metatarsophalangeal dislocation: Outside this series, dislocation of the proximal phalanx dorsally has been observed in two feet, in both cases the sesamoids were observed widely separated from the proximal phalanx accompanied by severe interphalangeal clawing. As far as lateral dislocation is concerned, radiographs of other toes in the series suggest a pre-dislocation position (Figure 14), and lead to the conjecture that erosive collapse of the medial phalangeal base at



Figure 12 Photograph of a great toe with the soft tissue attachments to the proximal phalanx. The metatarsal head has been removed to show the spherical socket in which it lies composed of the phalangeal base, sesamoid bones and the surrounding soft tissues. The cartilage surfaces have been coloured in order to highlight them.

due to dislocation but persists beneath the great toe even if grossly deformed, the one exception being hallux elevatus. One cannot escape the conclusion that the first metatarso-phalangeal joint is

not only more important functionally, more diverse pathologically and more disabling clinically, but fundamentally distinctive structurally from the other metatarso-phalangeal joints. We believe one important factor is the presence and contribution of the sesamoids beneath the first metatarsal head and most important is their close and strong musculo-ligamentous connections to the base of the proximal phalanx under most circumstances. Indeed we suggest that the sesamoids functionally extend the phalanx proximally creating a deep 'socket' for the 'ball' of the metatarsal head (Figure 12), which explains why dislocation is rare, for the articulation is virtually a 'captured joint'. Moreover, this capture enables alarming degrees of subluxation to develop and be maintained, e.g. 90° of hallux valgus, and dictates that although the sesamoids themselves may dislocate on the metatarsal head, the proximal phalanx adapts by rotating on its long axis medially with valgus and laterally with varus.

Hallux valgus. The strong tendinous and muscular attachments securing the sesamoids to the phalanx are also components in the muscle imbalance at the metatarso-phalangeal joint after and possibly before subluxation reaches 20° . The lateral half of flexor hallucis brevis and adductor hallucis secure a mechanical advantage which overcomes the medial half of flexor hallucis brevis and the abductor (Figure 11). Progressive hallux valgus may be encouraged by unsuitable footwear and metatarsus primus varus if not initiated by them, also dislocation and lateral drift of the lesser toes leave space which the hallux can occupy. Metatarsus primus varus may be aggravated by severe valgus when the strong lateral muscles act on the phalanx and sesamoids which may push the metatarsal head medially, in particular, when the lateral sesamoid dislocates between the first and second metatarsal heads (Figure 13).

PROCEEDINGS OF THE DANISH ORTHOPAEDIC SOCIETY

(Copenhagen 2), 30 April 1977

EDITOR A. J. HOUM

CUBITAL TUNNEL SYNDROME TREATED WITH SIMPLE DECOMPRESSION

Per B. Thomsen

A follow-up study (observation time 7 months to 5 years) of 32 decompression operations in 31 patients with cubital tunnel syndrome treated during a 5 year period revealed complete recovery in 16 patients, varying improvement in 13 and no improvement in 3 patients.

This method gives results equal to those obtained with the traditional operative methods—anteposition and medial epicondylectomy—i.e. about 75 per cent excellent plus good results. The method is easy and rapid to perform and free of complications.

A case of supracondylar process of the humerus with compression of the ulnar and median nerves treated with subperiosteal resection of the spur is discussed.

AVASCULAR NECROSIS OF THE TROCHLEA OF THE TALUS

Jørgen Fuldgård Lørrén et al.

On the basis of an analysis of 218 consecutive cases of talar fracture or subtalar dislocation it could be concluded that a connection exists between the morphology of the talar injury and the incidence of trochlear necrosis. This connection can be explained by the relation of the injury to the anatomical course of the three main vascular supplies of the trochlea. After injuries involving one of the three main channels the incidence of necrosis is about one in twenty after injuries involving two main channels it is one in four and if the injury involves all three main vascular supplies so that for a time the trochlea is entirely avascular necrosis will occur in about two thirds of the cases. Thus on the basis of our knowledge concerning the vascular supply of the trochlea it is possible to assess the risk of osteonecrosis according to the morphology of the individual talar injuries.

LESIONS OF LARGE ARTERIES

A. J. HOUM, COPENHAGEN

Sixteen patients with lesions of large arteries complicating fractures or dislocations of the lower limbs are presented. Only four of the patients were brought to vascular surgical treatment within 6 hours after the injury and good end results without residual disability were obtained in all four patients. Amputation proved necessary in seven of the 12 patients who received vascular surgical treatment more than 6 hours after the injury and two patients developed permanent disabilities in the form of muscular necroses and pareses. Thus only three of the patients in whom vascular surgical treatment was instituted at a late stage did not develop permanent sequelae. The explanations for the late treatment are defective primary diagnosis and prolonged transport of the patients. On the basis of these findings early arteriography or transfer of patients suspected of having arterial lesions is recommended or possibly, the summoning of a vascular surgical team could be considered.

AMPUTATIONS IN A DANISH COUNTY CHANGES OVER 5 YEARS

IN INCIDENCE AND LEVEL
Stein Christensen

Following a previous investigation of amputations in a Danish county (1961-1971) a new study (1975/76) showed a slight increase in incidence, from 14.9 to 18.2 per 100 000 inhabitants per year. It is now possible to preserve the knee in 56 per cent of the diabetic patients and in 23 per cent of the arteriosclerotics.

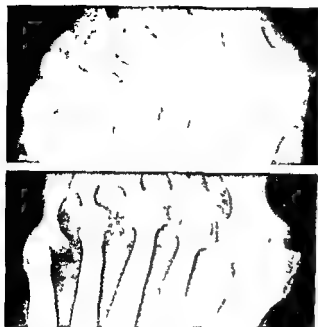


Figure 14 Predislocation

A Collapse of the medial corner of the proximal phalanx in progress

B Proximal phalangeal erosion with integrity of the medial corner of the phalanx preventing complete dislocation

the attachment of abductor hallucis is a necessary prelude to dislocation perhaps hastened by previous valgus and tortus deviation. Such collapse is a sequel to severe joint destruction which probably facilitates the tendency to subsequent fusion. To emphasise a point already postulated, the sesamoids remain anatomically tied to, and thus functionally an extension of, the proximal phalanx forming a plantar ledge preventing dorsal dislocation on the metatarsal head but ensuring rotation additional to valgus (Figure 12).

We suggest that weight-bearing prevents plantar dislocation and assume that foot wear stops medial dislocation.

REFERENCES

- Bonney, G. & Macnab, I. (1952) Hallux valgus and hallux rigidus *J Bone Jt Surg* 34 B 366-385.
- Dixon, A. St J. & Gheith, S. I. (1973) Tangential X ray of the forefoot in rheumatoid arthritis *Ann rheum Dis* 32, 92-93.
- Dixon, A. St J. (1971) Personal communication.
- Itzgerald, J. A. W. (1969) A review of the long term results of arthrodesis of the first metatarsophalangeal joint *J Bone Jt Surg* 51 B 488-493.
- Hardy, R. H. & Clapham J. C. R. (1951) Observations on hallux valgus *J Bone Jt Surg* 33 B 376-391.
- Kessel, L. & Bonney, G. (1958) Hallux rigidus in the adolescent *J Bone Jt Surg* 40 B 669-673.
- Mercer, W. & Duthie, R. B. (1964) *Orthopaedic surgery* Sixth edition, p. 937 Edward Arnold Ltd, London.
- Ropes, M. W., Bennett, G., Cobb, S., Jacob, R. & Jessar, R. A. (1959) Diagnostic criteria for rheumatoid arthritis 1958 revision *Ann rheum Dis* 18 49-53.
- Steinbrocker, O., Traeger, C. H. & Batterman, R. C. (1949) Therapeutic criteria in rheumatoid arthritis *J Amer med Ass* 140, 659-662.
- Vainio, K. (1956) The rheumatoid foot, a clinical study with pathological and roentgenological comments *Ann Chir Gynaec Fenn Supplement* 1.
- Vidigal, I., Jacoby, R. K., Dixon, A. St J., Ratcliffe, A. H. & Kirkup, J. (1975) The foot in chronic rheumatoid arthritis *Ann rheum Dis* 34 292-297.
- Wood Jones, F. (1944) *Structure and function as seen in the foot* p. 1-2 Bailliere, Tindall & Cox, London.

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was given to working capacity and residual pain. Seven patients had improved, one was unchanged and three were worse. Thus the results were not as favourable as is usual for this operation in rheumatoid arthritis.

III. OSTEOCLASTOMA AN EVALUATION OF MALIGNANCY IN RELATION TO MICROSCOPIC FINDINGS T. Schiødt, I. Dissing, J. Heerfordt & O. Snæppen

A 10 year series of bone tumours from "Rigshospitalet" and Radiumstationen, Copenhagen, contained 12 osteoclastomas, the malignancy of which was graded by Jaffe's method. Two cases were classified as grade I, five as grade II and five as grade III. Clinical follow up showed that four patients had died from their tumours, one died in an accident—presumably with recurrent tumour, while seven were alive, six of whom showed no clinical recurrence. Apparently the correlation between degree of malignancy and clinical course was quite good, but the material is too small for reliable conclusions. The general attitude in the literature to malignancy grading is reserved and any case of osteoclastoma should be considered potentially malignant.

TECHNETIUM SCINTIGRAPHY OF INTRACAPSULAR FRACTURES OF THE FEMORAL NECK B. Zdravkovic, A. B. Christensen, H. Erichsen, O. Harling & S. P. Nielsen

A prospective investigation of 25 patients with intracapsular fractures of the femoral neck was carried out with special attention to the early diagnosis of necrosis of the femoral head. Technetium scintigrams were made 14 days, 3, 6 and 12 months after the fracture. The results showed that patients with necrosis of the femoral head had increased activity over the caput, but the difference was not statistically significant.

The treatment of 19 patients with histologically proven chondrosarcomas was: amputation in 11, local excision in 7 and X-ray treatment in 3 cases. Thirteen patients survived more than 2 years, eight more than 5 years and two more than 10 years. 5 x developed local recurrences, four of them after excisions and two after subtotal hemipelvectomy. Four patients developed pulmonary metastases.

Chondrosarcoma runs a slow course and

shows a great tendency to local recurrence and late pulmonary spread. The histological diagnosis is very difficult and discrepancies between histological picture and clinical course are found. Surgery is the only treatment.

OSTEOGENIC SARCOMA A PROGNOSTIC EVALUATION I. Dissing, J. Heerfordt, T. Schiødt & O. Snæppen

The treatment of 49 patients with histologically confirmed osteosarcomas was amputation in 42 and X-ray treatment in 6 cases. Twenty-two patients survived more than 2 years and 13 more than 5 years. Twenty-six patients developed pulmonary metastases, 15 within 11 months. Seventeen of the 26 patients died within 6 months after diagnosis of the metastases. One patient lived 4 years after pulmonary resection.

No patient received chemotherapy after the operation.

SPONTANEOUS REGRESSION IN A CASE OF MALIGNANT PRIMARY BONE TUMOUR J. Heerfordt, I. Dissing, T. Schiødt & O. Snæppen

In 1971 a 36 year old male patient with a benign chondroma of the clavicle was operated on. The histological picture was that of a malignant transformation in a benign chondroblastoma. The lesion was inoperable and neither radiation nor chemotherapy was given. Symptoms and radiographic changes progressed until 1973, then they regressed. By 1975 the patient was free of disease.

A small number of similar cases of possible spontaneous regression of malignant primary bone tumours.

SLIDING SCREW PLATE IN THE TREATMENT OF TROCHANTERIC FRACTURES J. Steen Jensen, A. Møsting & E. Tøndevold

Technical complications such as penetration, breakage or bending of implants are encountered in 15-25 per cent of unstable trochanteric fractures.

A series of 42 patients treated by the sliding screw plate described by Clawson is reviewed. 25 fractures united in the postoperative position.

STABILITY OF THE HIP IN CHILDREN EVALUATED FROM A SINGLE RADIOGRAPH

J. Reimers

Stability of the hip can be evaluated on an antero-posterior radiograph of the pelvis by determining the percentage migration of the femoral head beyond the acetabular rim. Out of 32 Danish orthopaedic departments four employ a single radiograph, the others use two or more positions. Sixty-six deformed hips in patients with cerebral palsy were studied in neutral and in maximum inward rotation. A correlation coefficient of $r = 0.89$ was obtained and the differences in percentage migration were small enough to be ignored. Since even a severely subluxated hip will become reduced on abduction of the leg, a single knee together antero-posterior radiograph suffices.

EXPLORING WITH THE SCANNOR TOTAL HIP REPLACEMENT

V. J. Holm, A. Mossing & A. Janssen

A total of 205 operated hips were studied after a follow-up time of from 1 to 5 years. The mortality was 2 per cent, deep infection rate 1 per cent and luxation rate 5 per cent. 177 patients were examined according to Merle d'Aubigné and showed considerable gain in all three scores, most markedly in the pain rating. There were 25 cases of slight complications and 20 cases of serious complications. 10 patients required various forms of revision.

MAIACIA OF THE OS LUNATUM TRIATED WITH SHORTENING OSTIOTOMY OF THE RADIUS

J. Quesen

In the period 1970-1976 seven patients—six men and one woman—have been treated for malacia of the os lunatum. In all cases the treatment was osteotomy to reduce the length of the radius by 5 mm. The average age of the patients was 37 years and the average observation time was 34 months.

The preoperative symptoms of all patients were tenderness at palpation, pain on lifting and on moving. Four patients had pain at rest. Radiological examination showed a *minus* variance of the ulna in four patients.

Postoperative control revealed one patient with tenderness at palpation and pain on moving. The remaining six patients were free from pain. Radiological examination showed the os lunatum structure of the os lunatum to be unchanged in five patients in progression in one patient and in regression in one patient.

INTRACARDIAL ARTHROGRAPHIC STUDY IN AMPUTATED RABBITS

C. Hansen, Ieth & A. Karle

The vascular changes in rabbits after amputation were studied *in vivo* with arteriography after intracardial injection of contrast.

In the amputated extremity an initial vasoconstriction of the arteries was found. Thereafter changes were observed in arteries and veins both in the operated and contralateral extremities depending on the level of amputation and the manner in which the stump was closed. When no myoplasty was carried out, arteriovenous shunts were formed in the stump caused by the inactivity of the muscles. Myoplasty counteracts muscle inactivity and the development of arteriovenous shunts and so improves the muscle blood flow in the stump.

PRELIMINARY REPORT WITH ARTHROSCOPY OF THE KNEE JOINT USING THE DYONICS NEEDLESCOPE™

F. Bertelsen & V. Damholt

At the Department of Orthopaedic Surgery, Odense Hospital, arthroscopy of 81 knee joints using the Dyonics Needlescope (standard model) was performed over a 4-month period. 74 patients were predominantly 20 to 40-year-old males. An antero-lateral approach under general anaesthesia was routinely employed. No complications were observed. In 55 knees with primary indication for surgery, the clinical diagnosis was correct in 39 cases, whereas arthroscopy yielded 49 correct preoperative diagnoses.

In 31 knees without primary indication for surgery (mean observation period 6 months), arthroscopy revealed 10 cases suitable for operative treatment, while in 21 knees the diagnosis was confirmed, supplemented or corrected.

RESECTION OF THE CAPITULUM ULNAE IN TRAUMATIC LESIONS OF THE WRIST

I. Moulvad & J. Sommer

In the Department of Orthopaedic Surgery, Århus County Hospital, 11 wrists in 10 patients with traumatic capitulum ulnae syndrome were treated with resection of the distal end of the ulna during the period 1972 to 1976. Seven out of a total of 954 patients (0.8 per cent) were operated because of fracture of the distal end of the radius.

Preoperatively special attention was given to pain on rotation, reduction of strength and radiological changes. The interval between the trauma and surgery was approximately 9 months. At the follow-up an average of 21 years after the operation, special consideration

was given to working capacity and residual pain. Seven patients had improved, one was unchanged and three were worse. Thus the results were not as favourable as is usual for this operation in rheumatoid arthritis.

THE OSTEOCLASTOMA **A EVALUATION OF MALIGNANCY IN** **RELATION TO MICROSCOPIC FINDINGS** *T. Schiødt, I. Dissing, J. Heerfordt & O. Sjøneppen*

A 10 year series of bone tumours from Rigs hospital and "Radumstasjonen", Copenhagen contained 12 osteoclastomas the malignancy of which was graded by Jaffe's method. Two cases were classified as grade I, five as grade II and five as grade III. Clinical follow up showed that four patients had died from their tumours, one died in an accident—presumably with recurrent tumour while seven were alive, six of whom showed no clinical recurrence. Apparently the correlation between degree of malignancy and clinical course was quite good, but the material is too small for reliable conclusions. The general attitude in the literature to malignancy grading is reserved and any case of osteoclastoma should be considered potentially malignant.

PROSPECTIVE INVESTIGATION OF 25 PATIENTS WITH **INTRACAPSULAR FRACTURES OF THE FEMORAL NECK WAS** **CARRIED OUT WITH SPECIAL ATTENTION TO THE EARLY** **DIFFERENCE**

A prospective investigation of 25 patients with intracapsular fractures of the femoral neck was carried out with special attention to the early difference.

patients with necrosis of the femoral head had increased activity over the caput but the difference was not statistically significant.

CHONDROSARCOMA **A PROGNOSTIC EVALUATION** *I. Dissing, J. Heerfordt, T. Schiødt & O. Sjøneppen*

The treatment of 19 patients with histologically proven chondrosarcomas was amputation in 8, local excision in 7 and X-ray treatment in 3 cases. Thirteen patients survived more than 2 years, eight more than 5 years and two more than 10 years. Six developed local recurrences, four of them after excisions and two after subtotal hemipelvectomy. Four patients developed pulmonary metastases.

Chondrosarcoma runs a slow course and

shows a great tendency to local recurrence and late pulmonary spread. The histological diagnosis is very difficult and discrepancies between histological picture and clinical course are found. Surgery is the only treatment.

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No patient received chemotherapy after the operation.

SPONTANEOUS REGRESSION IN A CASE **OF MALIGNANT PRIMARY BONE TUMOUR** *J. Heerfordt, I. Dissing, T. Schiødt & O. Sjøneppen*

In 1971 a 36 year old male presented with extensive pelvic destruction. Biopsy showed benign

highly differentiated chondroblastic osteosarcoma or a malignant transformation in a benign chondroblastoma. The lesion was resectable and neither radiation nor chemotherapy was given. Symptoms and radiographic changes progressed until 1973, then they regressed. By 1975—and till now—no symptoms remain and radiographies show healing with sclerosis. No metastatic spread was noted. In the literature there are a small number of similar cases of possible spontaneous regression of malignant primary bone tumours.

SLIDING SCREW PLATE IN THE TREATMENT **OF TROCHANTERIC FRACTURES** *J. Steen Jensen, A. Møssing & E. Tøndevold*

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In 31 knees without primary indication for surgery (mean observation period 6 months), arthroscopy revealed 16 cases suitable for operative treatment, while in 21 knees the diagnosis was confirmed, supplemented or corrected.

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J Moutard & J Sommer

In the Department of Orthopaedic Surgery, Aarhus County Hospital, 11 wrists in 10 patients with traumatic caput ulnae syndrome were treated with resection of the distal end of the ulna during the period 1972 to 1976. Seven out of a total of 934 patients (0.8 per cent) were operated because of fractures of the distal end of the radius.

Preoperatively special attention was given to pain on rotation, reduction of strength and radiological changes. The interval between the trauma and surgery was approximately 9 months. At the follow up, an average of 21 years after the operation, special consideration

PROCEEDINGS OF

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EDITOR A ALHO

ELECTRICAL STIMULATION OF FRACTURE HEALING

A J Aho, H Aro & T Elfers

Department of Surgery and Department of
Pathological Anatomy
Turku University Central Hospital

We examined the effect of asymmetrical alternating current on the bone healing process in the rabbit antebrachium. The voltage supplied simulated a physiological pattern of stress generated electrical potentials in bone. A transistorized multivibrator (Ollituote Oy Finland) delivering asymmetrical alternating current was used. The current supplied had positive and negative peaks (+22 μ A and -18 μ A in the radius group, +100 μ A and -100 μ A in the ulna group) and a small unidirectional current (+2 μ A in both groups). The frequency was 68 Hz, pulse duration 8 ms and voltage limit 1 V.

In the radius group the current was led into the osteotomized bone with teflon insulated platinum-iridium leads. In the ulna group the osteotomy site was externally transfixated with two Kirschner wires which were used as electrodes.

In the two stimulated groups histological studies revealed an activated osteogenesis near the electrodes, particularly in the periosteum which was more pronounced than the reaction at the fracture site. Both electrodes induced osteogenesis. In the control groups the osteogenic reaction around the electrodes was either minimal or else non-existent.

a strong osteogenetic capacity (Ritsila et al 1972, Scand J Plast Reconstr Surg 1979). Periosteum alone and periosteal grafts attached to 200 μ thick cortical bone were grafted from the tibia to a lumbar vertebra in 6 week-old rabbits. The grafts were fixed bilaterally to the same vertebra between the spinous and mammillary processes. The rabbits were killed 3, 7, 14, 21 and 28 days later and osteogenesis was examined histologically. It was found that freely stripped periosteum had better osteogenetic power than the 200 μ thick osteoperiosteum. The new bone was formed by the osteogenetic cells of the cambium layer. In the present study the osteoperiosteal grafts were relatively thick. A further study using thinner grafts is being performed.

ENDOPROSTHETIC REPLACEMENT OF THE KNEE JOINT

Per Slatia & Uolevi Kankkaanpää

Division of Orthopaedic Surgery and
Traumatology, Surgical Clinics, Helsinki

Twenty-one patients with rheumatoid arthritis and eight patients with osteoarthritis of the knee were treated with an endoprosthetic replacement of the deranged joint surfaces. The main indications in addition to pain were severe lateral instability in nine knees and flexion contracture ranging from 20 to 50° in 19 knees. Two types of prostheses were used, viz., the Geomedic and the Marmor modular knee. Follow-up averaged 12 months. Arthroplasty provided almost complete relief of pain in 20 patients, corrected lateral stability in seven out of nine unstable knees and relieved completely the flexion contracture in 11 out of 19 knees. The average range of movement increased from 78° preoperatively to 90° at follow-up.

Orthopaedic Hospital of the Invalid Foundation
Helsinki

Earlier studies have shown that free periosteum stripped from the tibia with a scalpel has

tion while telescoping of the implant was encountered in 18 cases leading to bony support and stable weight transmission over the fracture line. Penetration of the screw occurred in only two patients but in neither case was reoperation indicated.

In conclusion the sliding screw plate is recommended in the treatment of unstable trochanteric fractures, as it permits early weight bearing and technical errors are not encountered.

were operated on during the period 1974-1976. The mean age of the patients was 29.8 years and the time interval between the trauma and surgery was more than 3 years. The pseudarthrosis was in each case located in the middle third of the clavicle. The indication for surgery was pain. A skin incision was performed cranio-caudally to avoid damaging the cutaneous nerves. The ends of the pseudarthroses were renewed and the reposition fracture was fixed with AO semitubular plates and cancellous bone transplants from the iliac crest. It was possible to treat a 1 inch defect successfully without bone interposition. Postoperative immobilisation was maintained with a collar and cuff for 3 weeks. All operated pseudarthroses consolidated and the patients returned to work within 2 months of the operation. In primary treatment of fractures of the clavicle the conservative method gives good results in most cases and in the treatment of pseudarthrosis an AO semitubular plate with cancellous bone transplantation is recommended.

EARLY COMPLICATIONS OF DISLOCATION OF THE HUMERUS

H. Pasila, H. Jaroma, O. Kivimäki &
A. Sandholm

Department of Orthopaedics and Traumatology
Helsinki University Central Hospital

Complications of traumatic dislocation of the humerus during the period 1973-1976 were analysed in a prospective study. The clinical examination was first made in the emergency department and later repeated in the department of physiotherapy. The function of the rotator cuff, peripheral pulses and motor and sensory function of the upper limb were examined.

Sixty-three patients out of 238 (26 per cent) showed the following associated lesions: brachial plexus 29, rotator cuff 28 and axillary nerve 21. Complications were more frequent in the age group over 50 years ($P < 0.001$) and in patients performing manual labour as opposed to those performing intellectual work ($P < 0.05$). If the humerus was dislocated for longer than 12 hours the frequency of complications was higher ($P < 0.01$).

The importance of early reduction is emphasized.

INTERCONDYLAR Y SHAPED FRACTURES OF THE HUMERUS

Vappu Lusaad

Department of Orthopaedics and Traumatology
Helsinki University Central Hospital

158 patients aged 15-90 with 159 intercondylar Y shaped fractures of the humerus were treated

during the period 1960-1972. Two thirds of the 91 female patients were 55-90 years of age, almost half of the male patients were aged 15-35 years. 114 patients with 115 fractures were re-examined the average follow up period being four and a half years. According to the Roseborough-Radin classification there were 24 cases of type I, 44 cases of type II, 44 cases of type III, and 27 cases of type IV fracture. The female patients had had low energy accidents (falling), the male patients mainly high energy accidents (working traffic). One fracture in four was open. Four primary nerve injuries were noted. 80 patients were treated conservatively: closed reduction and plaster cast immobilization or skeletal traction and plaster cast were used. 78 patients were treated operatively. 34 cases with in the first 24 hours. A great variety of fixation methods were used: Vitallium screws and plates, and Kirschner wires were used throughout the whole period, with AO-osteosynthesis being the most popular method in the latter years. 19 cases of postoperative nerve injuries were observed. 10 patients developed chronic fistulation and five of them had open fractures. Five cases of pseudarthrosis were noted, two of them after conservative treatment.

TREATMENT OF FUNCTIONAL DISORDERS AFTER MALPOSITION OF FRACTURES OF THE DISTAL RADIUS

K. A. Solonen & T. Telaranta

Orthopaedic Hospital of the Invalid Foundation
Helsinki

Fifty-six patients with malposition after a fracture of the distal radius are reviewed. The patients initially had conservative treatment at different out-patient departments. The deformity was observed to limit movement of the radioulnar joint but movement of the radiocarpal joint was also restricted in most of the cases.

Depending on the degree and the nature of the deformity and the limitation of joint movement two methods were used. The worst deformities were corrected by a distal wedge osteotomy of the radius according to the angulation. The distal fragment was fixed in the corrected position with two Kirschner wires. Most frequently a modified Darrach procedure was included in the operation: the length of the ulna resected did not exceed 2 cm. The postoperative plaster splint was removed after 6 to 8 weeks. In the cases where the deformity caused limitation in pronation-supination only a distal resection of the ulna was considered to be sufficient.

Median nerve compression symptoms were reported in 11 per cent of the patients. These symptoms disappeared in most of the patients.

ARTHROPLASTY OF THE KNEE JOINT WITH SPECIAL REGARD TO COMPLICATIONS

Vahonen

Aurora Municipal Hospital Helsinki

A study of arthroplasty of 73 knee joints was made with an average follow up of two and a half years. All operations were performed by the same orthopaedic surgeon in the department of general surgery. Modular and polycentric prostheses were used in most cases and the average age of the patients at the time of the operation was 60 years. Most had rheumatoid arthritis. The rate of deep infection was 5.5 per cent (four cases) and that of failure 18 per cent. Fractures of the prosthesis or bone were found in five knees. All the fractures were in the medial compartment of the knee joint. Loosening of the prosthesis without infection or other complications was found in three cases, all of which became apparent within 1 year of the operation. All failures were reoperated on. An arthrodesis was performed on seven knees (9.6 per cent). These knees were evaluated as poor at the late follow up stage. The prosthesis of five patients was changed and one knee was treated by closed irrigation. All infections healed during the follow up. The best results were achieved with the Geomedic and St. Georg-Schlihten prosthesis models.

OPERATIVE TREATMENT OF THE RHEUMATOID CERVICAL SPINE

Uolevi Kankaanpää

Division of Orthopaedic Surgery and

Traumatology, Surgical Clinics Helsinki

Rheumatoid arthritis more often involves the upper than the lower part of the cervical spine. In the upper cervical spine dislocation is caused mainly by ligamentous destruction. Because of the large upper medullary canal the subluxation seldom results in medullary symptoms. Radicular pains are however quite common. In the lower cervical spine dislocation is caused by bony destruction of articular facets. Because of the narrower lower medullary canal even slight dislocation may be dangerous.

Since 1972 28 patients have been operated on at Rheuma Foundation Hospital Heinola and Surgical Clinics Helsinki. Brattstrom's method of occipito axial fusion with cement and bone was used in 14 cases (Brattstrom & Granholm 1973 Orthopädie 2: 118-120). Gallie atlanto axial fusion was performed in seven patients. The remaining seven patients suffered from C3-C4 dislocations. They were operated on using Rogers method (simple) one transplantation or laminectomy plus lateral fusion.

One tetraplegic patient showed no improvement whereas the two tetraparetic patients re-

covered almost completely. At the follow up of 23 patients their subjective evaluation of the result was good in 15, fair in 5 and unimproved in 3. Two complications were recorded: one infection (necessitating the removal of cement 6 months later) and one broken wire between the atlas and cord (with no medullary injury but requiring removal of the wire).

There seems to be an increased tendency for the occurrence of lower cervical dislocations 4-6 years after occipito axial fusion.

STRESS HORMONES, LIPIDS AND COAGULATION IN TRAUMA PATIENTS WITH AND WITHOUT FAT EMBOLISM: A COMPARATIVE STUDY 1 YEAR AFTER SEVERE TRAUMA

Atikainen K, Willman J, P. Rohkanen
Orthopaedic Department, Central Hospital of Central Finland Jyväskylä

The question of why some patients develop fat embolism syndrome (FES) while others with similar injuries do not remains unsolved. Ten patients with FES were compared with 10 patients with similar injuries without FES at least 1 year after trauma. The following blood tests were performed: Hb, leucocytes, platelets, protein and lipid electrophoresis, ACTH, cortisol, TSH, HGH, insulin, glucose, APTT, certain coagulation studies, a trypsin and antithrombin III. In FES platelet counts were higher especially after ergometric stress ($P < 0.01$). More numerous petechiae were observed in the FES group in a Rumpel-Leede stasis test. Fibrinogen was somewhat higher in FES and the alpha/beta ratio in lipoprotein electrophoresis somewhat smaller. Cortisol was lower after stress in the control group ($P < 0.05$). Low pH values were observed in the FES group ($P < 0.05$). Blood glucose was pathological in three patients in the FES group and the values rose after ergometric stress while in the control group glucose was normal in all and decreased after stress in most. Half the patients with FES had a familial history of diabetes against none in the control group. Urinary catecholamine were somewhat higher in FES but the reaction to stress was similar in both groups.

PSUEDARTHROSIS OF THE CLAVICLE

Joukunen E, Karaharju

Division of Orthopaedic Surgery and

Traumatology, Surgical Clinics Helsinki

Fractures of the clavicle are usually treated conservatively. If the fracture remains unhealed and a painful pseudarthrosis develops, an operation may be indicated. At the Surgical Clinics five patients with pseudarthrosis of the clavicle

were operated on during the period 1974-1976. The mean age of the patients was 29.8 years and the time interval between the trauma and surgery was more than 3 years. The pseudarthrosis was in each case located in the middle third of the clavicle. The indication for surgery was pain. A skin incision was performed cranio-caudally to avoid damaging the cutaneous nerves. The ends of the pseudarthroses were resected and the reposition fracture was fixed with 40 semitubular plates and cancellous bone transplants from the iliac crest. It was possible to treat a 1 inch defect successfully without bone interposition. Postoperative immobilisation was maintained with a collar and cuff for 3 weeks. All operated pseudarthroses consolidated and the patients returned to work within 2 months of the operation. In primary treatment of fractures of the clavicle the conservative method gives good results in most cases and in the treatment of pseudarthrosis an AO semitubular plate with cancellous bone transplantation is recommended.

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covered almost completely. At the follow up of 23 patients their subjective evaluation of the result was good in 15, fair in 2 and unimproved in 3. Two complications were recorded: one infection (necessitating the removal of cement 6 months later) and one broken wire between the atlas and axis (with no medullary injury but requiring removal of the wire).

There seems to be an increased tendency for the occurrence of lower cervical dislocations 4-5 years after occipito-axial fusion.

STRESS HORMONES, LIPIDS AND COAGULATION IN TRAUMA PATIENTS WITH AND WITHOUT FAT EMBOLISM: A COMPARATIVE STUDY 1 YEAR AFTER SURFAC TRAUMA

J. Aikainen & P. Wallman & P. Rokkanen
Orthopaedic Department, Central Hospital of Central Finland, Jyväskylä

The question of why some patients develop fat embolism syndrome (FES) while others with similar injuries do not remains unsolved. Ten patients with FES were compared with 10 patients with similar injuries without FES at least 1 year after trauma. The following blood tests were performed: Hb, leucocytes, platelets, protein and lipid electrophoresis, ACTH, cortisol, TSH, GH, insulin, glucose, APTA, certain coagulation studies, a antitrypsin and antithrombin III. In FES platelet counts were higher especially after ergometric stress ($P < 0.01$). More numerous petechiae were observed in the FES group in a Rumpel-Leede stasis test. Cholesterol was somewhat higher in FES and the alpha/beta ratio in lipoprotein electrophoresis somewhat smaller. Cortisol was lower after stress in the control group ($P < 0.05$). Low pH values were observed in the FES group ($P < 0.005$). Blood glucose was pathological in three patients in the FES group and the values rose after ergometric stress while in the control group glucose was normal in all and decreased after stress in most. Half the patients with FES had a familial history of diabetes against none in the control group. Urinary catecholamines were somewhat higher in FES but the reaction to stress was similar in both groups.

PSUDARTHROSIS OF THE CLAVICLE

J. Joulinen & I. Karaharju
Division of Orthopaedic Surgery and Traumatology, Surgical Clinics Helsinki

Fractures of the clavicle are usually treated conservatively. If the fracture remains unhealed and a painful pseudarthrosis develops, an operation may be indicated. At the Surgical Clinics five patients with pseudarthrosis of the clavicle

were operated on during the period 1974-1976. The mean age of the patients was 29.8 years and the time interval between the trauma and surgery was more than 3 years. The pseudarthrosis was in each case located in the middle third of the clavicle. The indication for surgery was pain. A skin incision was performed cranio-caudally to avoid damaging the cutaneous nerves. The ends of the pseudarthroses were resected and the reposition fracture was fixed with 40 semitubular plates and cancellous bone transplants from the iliac crest. It was possible to treat a 1 inch defect successfully without bone interposition. Postoperative immobilisation was maintained with a collar and cuff for 3 weeks. All operated pseudarthroses consolidated and the patients returned to work within 2 months of the operation. In primary treatment of fractures of the clavicle the conservative method gives good results in most cases and in the treatment of pseudarthroses an AO semitubular plate with cancellous bone transplantation is recommended.

EARLY COMPLICATIONS OF DISLOCATION OF THE HUMERUS

M. Pasila, H. Jaroma, O. Kuusisto & A. Sundholm

Department of Orthopaedics and Traumatology
Helsinki University Central Hospital

Complications of traumatic dislocation of the humerus during the period 1973-1976 were analysed in a prospective study. The clinical examination was first made in the emergency department and later repeated in the department of physiotherapy. The function of the rotator cuff, peripheral pulses and motor and sensory function of the upper limb were examined.

Sixty-three patients out of 238 (26 per cent.) showed the following associated lesions: brachial plexus III, rotator cuff III and axillary nerve II. Complications were more frequent in the age group over 50 years ($P < 0.001$) and in patients performing manual labour as opposed to those performing intellectual work ($P < 0.05$). If the humerus was dislocated for longer than 12 hours the frequency of complications was higher ($P < 0.01$).

The importance of early reduction is emphasized.

during the period 1960-1972. Two thirds of the 91 female patients were 55-90 years of age, almost half of the male patients were aged 15-30 years. 114 patients with 115 fractures were re-examined the average follow-up period being four and a half years. According to the Risser-borough-Radin classification there were 24 cases of type I, 44 cases of type II, 44 cases of type III and 27 cases of type IV fracture. The female patients had had low energy accidents (falling), the male patients mainly high energy accidents (working traffic). One fracture in four was open. Four primary nerve injuries were noted, 80 patients were treated conservatively, closed reduction and plaster cast immobilization or skeletal traction and plaster cast were used, 78 patients were treated operatively, 34 cases within the first 24 hours. A great variety of fixation methods were used: Vitallium screws and plates and Kirschner wires were used throughout the whole period, with AO-osteosynthesis being the most popular method in the latter years. 19 cases of postoperative nerve injuries were observed, 10 patients developed chronic fistulation and five of them had open fractures. Five cases of pseudarthrosis were noted, two of them after conservative treatment.

TREATMENT OF FUNCTIONAL DISORDERS AFTER MALPOSITION OF FRACTURES OF THE DISTAL RADIUS

K. A. Solonen & T. Talaranta
Orthopaedic Hospital of the Invalid Foundation
Helsinki

Fifty-six patients with malposition after a fracture of the distal radius are reviewed. The patients initially had conservative treatment at different out-patient departments. The deformity was observed to limit movement of the radioulnar joint but movement of the radiocarpal joint was also restricted in most of the cases.

Depending on the degree and the nature of the deformity and the limitation of joint movement, two methods were used. The worst deformities were corrected by a distal wedge osteotomy of the radius according to the angulation. The distal fragment was fixed in the corrected position with two Kirschner wires. Most frequently a modified Darrach procedure was included in the operation: the length of the ulna resected did not exceed 2 cm. The postoperative plaster splint was removed after 8 to 8 weeks. In the cases where the deformity caused limitation in pronation-supination, only a distal resection of the ulna was considered to be sufficient.

Median nerve compression symptoms were reported in 33 per cent of the patients. These symptoms disappeared in most of the patients.

153 patients aged 15-90 with 159 intercondylar V-shaped fractures of the humerus were treated

after the osteotomy, but occasionally a discision of the volar carpal ligament was needed. One patient developed a full blown picture of a shoulder hand finger syndrome postoperatively. In the other patients the result was beneficial.

Osteotomy of the radius seems to be an advisable adjunct to the resection of the ulnar head in cases where the angular deformity of the radius is so severe that it significantly impairs radiocarpal movement.

IMAGE STORE FLUOROSCOPY IN SURGERY OF THE FRACTURED HIP

Kari Pietilä & Par Ståls

Division of Orthopaedic Surgery and Traumatology, Surgical Clinics, Helsinki

The recent development of radiographic image store devices permits the collection of consecutive radiographic images obtained during operative procedures. With image stores the automatic exposure time required for each picture is short and therefore the irradiation is correspondingly reduced and is considerably shorter than that with conventional pedal controlled continuous fluoroscopy.

The value of image store fluoroscopy in surgery of the hip was assessed in 54 patients whose fractures of the femoral neck or trochanteric region were treated with fixed angle AO/ASIF nails. In 34 patients reduction of the fracture and positioning of the nail were checked with conventional fluoroscopy. In 20 patients this evaluation was performed with a 100 picture store (VAS IS 100) attached to the X-ray device. The mean time of irradiation in the first group was 385 ± 168 seconds (SD) and in the second group 81 ± 48 seconds (SD). Thus image store fluoroscopy appreciably reduced the period of irradiation during the operation and additionally facilitated the accurate radiographic evaluation of each step in the operation.

POST TRAUMATIC SUBLUXATION OF THE PATELLA

A. Alho

Section of Orthopaedics and Traumatology, University of Bergen Hospital, Norway

Twelve patients were treated operatively for a subluxation of the patella. The cause was traumatic in all cases. The primary treatment had been conservative or none at all. Both sexes were equally represented. The age range was 18-44 years. The symptoms and signs were pain on weight bearing (all), giving away (10), mo-

mentary lockings (4), pain on resisted extension (5), and lateral instability of the patella (9). A tendency for subluxation was demonstrated in six cases by using Merchant X-ray projection (*J Bone Jt Surg* 1974 56 A, 1391). No pre-existing deformities of the knee were observed. A release incision of the lateral retinaculum was used in three cases. Campbell technique with release in six cases. Roux Goldthwait operation in one case and a combination of all these in two cases. Plaster immobilization was used for 2 to 6 weeks. Only detached fragments of chondromalacia present in seven cases were removed. Seven patients were totally symptom free and five had some pain on weight bearing after a follow up period of 1/2 to 3 years. It was concluded that post-traumatic subluxation of the patella is a distinct entity to be kept in mind in the flexion-abduction-external rotation injuries.

OSTEOTOMY IN TREATMENT OF COMPLICATED FRACTURES OF THE LOWER EXTREMITY

S. Santavirta & E. Karaharju

Division of Orthopaedic Surgery and Traumatology, Surgical Clinics, Helsinki

Hoffman's osteotomy is a therapeutic alternative in the treatment of severe primarily complicated fractures and infected pseudarthroses of the lower leg and femur. From 1973 to 1976 11 cases of this type were treated. In seven of these cases the fracture was located in the tibia. In three cases osteotomy was the primary treatment and in the remainder osteotomy was chosen after primary treatment had failed. In six patients primary treatment with osteosynthesis had resulted in an infection and osteotomy was chosen for further treatment. In the first stage the material of osteosynthesis was removed and a fixation was performed. In the second stage when the infection had ceased bone transplantation was performed while the external fixation stabilized the fracture area. The average time of frame immobilization was 150 days. One case resulted in amputation below the knee. Three fractures failed to consolidate despite cancellous bone transplantation. In seven fractures the osteotomy resulted in consolidation. In three of these cases bone transplantation had been necessary. Osteotomy can be recommended for the treatment of severe fractures with amputation often being the only alternative.

PROCEEDINGS OF THE NORWEGIAN ORTHOPAEDIC ASSOCIATION

Oslo January 15th, 1977

EDITOR ARNT JAKOBSEN

SYNOVECTOMY IN RHEUMATOID ARTHRITIS

Jens Te gland

Oslo Sanitetsforening Rheumatism Hospital
Oslo

The modern concept of systematic synovectomy in rheumatoid arthritis was initiated by Yarnio in 1951. The initial optimism has persisted in some clinics whereas others have expressed doubts regarding the long term results.

After 5 years or more there seems to be freedom from pain in about 80-90 per cent of cases. Recurrence of synovitis occurs in 20-30 per cent. The destructive process is stopped or retarded. A reduced frequency of recurrence is seen after operative techniques permitting maximal radi-
cality of synovectomy. Synovectomy in juvenile arthritis can normalize the disturbances of growth in the actual joint.

In this hospital synovectomies are performed in all joints of the upper and lower extremities and are carried out as totally as is technically possible.

SYNOVECTOMY OF THE ANKLE JOINT

Jan A. Pahlé

Oslo Sanitetsforening Rheumatism Hospital
Oslo

Sixty three cases of synovectomy of the ankle joint are reported. Eleven had juvenile arthritis, 50 had seropositive rheumatoid arthritis and two had psoriasis. Their ages ranged from 7-60 years.

An anterior midline and two curved incisions behind the lateral and medial malleoli with partial transection of the ligaments were used. In 23 cases postoperative immobilisation for 3 weeks in a plaster splint was used. In 40 cases active movements were started immediately. Partial weight bearing was permitted after 3 weeks.

Three years after the operation 46 patients are free from pain and swelling whereas 10 have tolerable pain. Of the remaining seven three have subsequently had an arthrodesis performed and one an arthroplasty. Improved stability was

obtained in 21 of the 38 cases with preoperative instability. In 17 patients the range of motion was slightly reduced, in 7 slightly increased.

In the same period 21 primary ankle arthrodeses were performed. These were triplearthrodeses if affection of the subtalar joint was present.

ARTHROPLASTY OF THE ANKLE JOINT

Jan A. Pahlé

Oslo Sanitetsforening Rheumatism Hospital
Oslo

Total replacement arthroplasty of the ankle joint *ad modum* Thompson has been performed with satisfactory preliminary results in seven

Postoperatively all are pain free with good stability which the side flanges of the tibial prosthesis seem to contribute to. The average postoperative dorsiflexion is 10° and plantar flexion 20°. Correct alignment of the prosthesis has been made technically easier after a slight modification of the original procedure. Active exercises are started immediately and partial weight bearing is allowed after 2 weeks.

Arthrodesis of the ankle joint has not been performed in the last year. If arthrodesis of the subtalar joint is indicated this should be done prior to the insertion of the ankle prosthesis.

AMYLOIDOSIS IN RHEUMATOID ARTHRITIS

Gunnar Haaug

Oslo Sanitetsforening Rheumatism Hospital
Oslo

A survey on amyloidosis in rheumatoid arthritis is given. Rheumatoid arthritis is an important primary disease predisposing to secondary amyloidosis as 5 per cent of the patients get this complication.

The major protein AA of secondary amyloid fibrils is of a non immunoglobulin nature. A serum protein SAA related to the amyloid pro-

tein AA is found in higher concentrations in diseases prone to secondary amyloidosis including rheumatoid arthritis. However, SAA is also increased in conditions without a predisposition to amyloidosis, quantitation of SAA can therefore not be used in the diagnosis of "risk", or early cases of amyloidosis.

Amyloidosis is a serious complication of rheumatoid arthritis. However, in many cases the prognosis seems to be better than thought previously. Such patients deserve the same, active therapeutic attitude as other rheumatoid patients.

HOGIA S DISAST

Paul Ierem

Oslo Sanitetsforening Rheumatism Hospital
Oslo

Four women, age 16-25 years, have been treated with excision of the fat pad of the knee joint, one bilaterally. Three have been relieved of their symptoms while in one the operation was performed too recently to judge the result.

The aetiology is discussed, trauma may be the cause. Once the condition occurs it seems that the patients enter a "vicious circle", and the treatment of choice is excision of the fat pad. Soft tissue X-ray, and arthroscopy may be useful in making the diagnosis.

ATLANTO AXIAL FIXATION IN RHEUMATOID ARTHRITIS

Jens Teigland

Oslo Sanitetsforening Rheumatism Hospital
Oslo

A videotape was shown of the technique of radiological examination, the symptoms and signs and the operative fixation in atlanto axial luxation *ad modum* Brattstrom Granholm.

The videotape also dealt with a technique for measuring the spinal fluid pressure with a transducer, showing the special pressure pattern elicited by compression of the jugular vein with the head in a neutral position in a ventroflexed and a dorsiflexed position. The videotape was produced in the Department of Rheumatoid Surgery in collaboration with the Department of Neurosurgery, Rikshospitalet Oslo.

Oslo, February 12th, 1977

CLEIDOCRANIAL DYSOSTOSIS

Tore Gronmark

Telemark Central Hospital, Skien

One case of cleidocranial dysostosis is reported. The aetiology, clinical picture and treatment of the lesion are discussed. Pseudarthrosis

of the clavicle and other clavicular abnormalities in cleidocranial dysostosis usually require no special treatment.

AN OPERATIVE TECHNIQUE FOR GENU RECURVATUM

Kåre Hadland

Telemark Central Hospital, Skien

A middle-aged woman with marked genu recurvatum caused by a previous hyperextension injury, was operated on using the following technique.

A long strip of the iliotibial band was dissected free preserving the insertion on the anterior aspect of the tibia. The strip was passed obliquely backwards, and pulled through a hole drilled transversely and as far posteriorly as possible through both femoral condyles. From here the strip was passed obliquely outside the medial capsule and under strong tension and with the knee in some degree of flexion, it was anchored on the anteromedial aspect of the tibia.

Immobilisation in a plaster cast was maintained for 3 months. The result was excellent.

SURGICAL TREATMENT OF DISLOCATION OF THE PERONEAL TENDONS

Tore Gronmark

Telemark Central Hospital, Skien

One case of dislocation of the peroneal tendons treated operatively by the method of Ellis Jones is reported. Early operation for dislocation of the peroneal tendons is advocated.

Oslo, March 12th, 1977

ORTHOPAEDICS IN A REGIONALIZED HEALTH SERVICE SYSTEM HEALTH REGION 6

Finar Sudmann

Regional Hospital in Tromsø, Tromsø

In Norway orthopaedic patients except those with acute trauma have been treated for the most part in the state hospitals in southern Norway. In 1974 Norway was divided into five health regions and the responsibility for an orthopaedic service was imposed on the individual regions.

To make an estimate of the need for orthopaedic beds per 1000 inhabitants in the fifth health region which is sparsely populated the mean hospital stay in 1975 for a selected patient material from three surgical departments in the region was recorded. For trauma cases orthopaedic and rheumatoid arthritis this was 141, 18 and 183 days respectively. Based on

these figures the estimate per 1000 inhabitants was assessed as trauma (musculoskeletal) 0.27, orthopaedic 0.30 and surgery for rheumatoid arthritis 0.08. The Regional hospital in Tromsø together with one Central hospital have less than half of the beds required. Accordingly, only after establishment of new orthopaedic services in the other Central hospitals in the region can the patients be given satisfactory service.

ANTERIOR DISPLACEMENT OF THE TIBIAL TUBEROSITY IN THE TREATMENT OF CHONDROMALACIA PATELLAE

Einar Sudmann & Berndt Salkowitsch
Regional Hospital in Tromsø, Tromsø

The preliminary results of 15 consecutive operations in 13 patients, eight men and five women, are reported. Age range 17-57 years. Chondromalacia of the femoral and tibial condyles was found in four knees and in one knee respectively, and meniscus tears were found in three. The diseased cartilage was removed. The mean anterior displacement of the tibial tuberosity was 12 mm.

Ten of the patients were improved, three of them resumed athletic activity. One patient was not improved, and in two the observation time was too short.

Postoperative infection occurred in one case.

ING A CIDENT

The preliminary results were assessed as satisfactory, and the complications were mainly caused by faulty operative technique.

CHRONIC ANTERIOR COMPARTMENT SYNDROME OF THE LEG

Einar Sudmann
Regional Hospital in Tromsø, Tromsø

The syndrome was made by exclusion. The paresis responded to blind diathermic fasciotomy.

The patients with ordinary physical exertion. The age range was 11-68 years. Three patients had paresis, and 14 neurological signs of affection of the fibularis profundus nerve. The syndrome responded well to blind diathermic fasciotomy. In the first 11 consecutive patients operated upon.

Most of the patients were females and had been misdiagnosed for years.

Oslo, April 16th, 1977

OVERGROWTH OF THE LIMB AFTER FRACTURE OF THE LOWER LEG IN CHILDHOOD

Geir Tøssgen Øjvind Hansen & Per Edvardsen
Regional Hospital, Trondheim

Eighteen patients treated for leg fracture in childhood were re-examined 8 to 10 years after the injury.

The limb length was examined radiologically, and the measurements included the tibia, the fibula and the femur on both sides. A slight overgrowth was found in the tibia. The tendency was more marked in oblique fractures and in the youngest children. No increase in growth rate was found in the femur or in the fibula.

The differences found were small, and in most cases without clinical significance.

AVULSION OF THE PATELLAR LIGAMENT IN A PATIENT WITH SPASTIC PARAPARESIS

Bjørn Samstad
Regional Hospital, Trondheim

An 11-year-old girl with spastic paraparesis detected when she was 1 year-old, had been able to walk with a walking frame on wheels. She had previously had tenotomies of the Achilles tendons because of equinovarus deformities.

Following sudden severe pain in both knees, she was examined clinically and radiologically. On the left side there was an avulsion of the lower pole of the patella, and on the right side an avulsion of the patellar ligament from its attachment to the tibial tuberosity. The patient also had 25° flexion contractures of both hips.

A releasing incision of the origin of the rectus femoris muscle was performed, combined with tenotomy of the reflected head of the same muscle bilaterally. The patient's complaints disappeared rapidly.

FAT EMBOLISM SYNDROME AFTER FRACTURE OF THE TIBIA

Stein Spenningsen
Regional Hospital in Trondheim, Trondheim

A 19-year-old previously healthy man with an uncomplicated fracture of the tibial shaft lost consciousness two days after the injury. He developed tachycardia and anaemia, and radiologically bilateral lung infiltrations. Despite lack of other signs of hypovolaemia, the urinary output was low with signs of renal failure.

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ORTHOPAEDICS IN A REGIONALIZED HEALTH SERVICE SYSTEM

HEALTH REGION 5

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Ten of the patients were improved, three of them resumed athletic activity. One patient was not improved and in two the observation time was too short.

Postoperative infection occurred in one case and thrombosis of the leg in one. The anterior displacement failed in one and one patient broke his leg in the operated diaphysis in a ski jumping accident.

The preliminary results were assessed as satisfactory and the complications were mainly caused by faulty operative technique.

CHRONIC ANTERIOR COMPARTMENT SYNDROME OF THE LEG

Einar Sudmann
Regional Hospital in Tromsø Tromsø

In a patient suffering from backache and paresis of the muscles of the anterior compartment of the leg the diagnosis of chronic anterior compartment syndrome was made by exclusion. The paresis responded to blind diathermic fasciotomy.

During the following 10 months this condition was especially looked for in patients with painful legs. Unexpectedly a similar syndrome was diagnosed in 11 patients with ordinary physical exertion. The age range was 11-68 years. Three patients had paresis and 14 neurological signs of affection of the fibularis profundus nerve. The syndrome responded well to blind diathermic fasciotomy. In the first 11 consecutive patients operated upon.

Most of the patients were females, and had been misdiagnosed for years.

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Søren Spenningsen
Regional Hospital in Trondheim Trondheim

A 69 year old previously healthy man with an uncomplicated fracture of the tibial shaft, lost consciousness two days after the injury. He developed tachycardia and anaemia and radiologically bilateral lung infiltrations. Despite lack of other signs of hypovolaemia the urinary output was low with signs of renal failure.

Clinical pulmonary signs were scanty. The patient died 5 days after injury.

Autopsy revealed multiple fat emboli in the lungs and brain and small haemorrhagic infarcts in all parts of the brain. Fat embolism syndrome after a tibial fracture is rare and especially so in this age group.

AVULSION OF THE ISCHIAL TUBEROSITY

Anders Dahle

Regional Hospital in Trondheim Trondheim

Four patients with avulsion of the ischial tuberosity, two boys and two girls are reported. The main symptom was pain in the buttock which started at the age of 12 to 15 years. Three had been injured during sports activities and in one patient the symptoms occurred after rowing without other trauma. The mechanism of the pain could in all patients be explained as overstretching of the hamstrings.

Two patients with complaints lasting 3 and 7 years respectively were operated upon. They had a non union of the apophysis which was removed with good results.

Stavanger, May 12th-14th, 1977

IMPLICATIONS WITH A STERILE OPERATING CHAMBER

Sierre Steie

Sanitex Hospital Sandnes

In September 1974 a sterile operating chamber was installed at this hospital. Up to November 1976 324 total hip replacement operations of medium Charnley were performed in the chamber. So far there have not been any primary or secondary signs of infection or loosening of the prostheses.

The sterile operating chamber has furthermore been in daily use for other types of bone operations.

At each operation two Petri dishes of blood agar have been placed on the floor of the chamber. For 1140 observations the growth has been 0.6 colonies per dish per hour.

DOES INDOMETHACIN (IMC) PREVENT POSTOPERATIVE ECTOPIC OSSIFICATION IN TOTAL HIP REPLACEMENT?

Kare Almdal & Per Røysland

Regional Hospital in Trondheim Trondheim

Fifty one operated hips in 73 patients were evaluated 3 months after operation. There were two main groups: 54 hips in patients not given IMC and 27 hips in patients given 25 mg IMC, 3 times daily the first 4 weeks postoperatively. The group without IMC showed a greater fre-

quency of high grade ossification while low grade ossification was equally frequent in the two groups. In the former group there were no signs of ectopic ossification in only 14 hips i.e. 26 per cent. In comparison no ossification was seen in 17 hips in patients given IMC i.e. 63 per cent.

It is concluded that IMC significantly prevents postoperative ectopic ossification following total hip replacement.

INDOMETHACIN HIPs

Helge Rønningen & Norvald Langeland

Sophies Minde Orthopaedic Hospital Oslo

The course of osteoarthritis in 294 hips of 186 patients was evaluated by examining their radiographs. The development of the disease in patients treated with indomethacin was compared with that in a control group. In the indomethacin group the disease progressed more frequently and in some parameters the progress seemed more severe. The results support previous reports indicating that indomethacin might have a deleterious effect on osteoarthritic hip joints. Some possible explanations for this adverse effect of indomethacin treatment are briefly discussed.

CONTROLLED INDUCED HYPOTENSION IN HIP SURGERY

M. A. Khalid Kahn & Ole Dankert Lunde

Sandnes Hospital Sandnes

The pharmacological basis, the technique, the indications and contraindications for the use of induced controlled hypotension were given. Fifty patients had a total hip replacement, arthroplasty and total Charnley 25 under controlled hypotension, 25 under normotension.

In the former group the perioperative haemorrhage was reduced to a fifth compared with the normotension group. The operative time was reduced by 15 per cent and the need for blood transfusions reduced by 50 per cent. A comparative study of nine bilateral cases gave identical results. There were no postoperative complications recorded in either of the groups.

FRACURE OF THE FEMORAL STEM AFTER TOTAL HIP REPLACEMENT

Pål Benum

Regional Hospital in Trondheim Trondheim

Three cases of fractured femoral stems of the Charnley Müller prosthesis are reported in males younger than 70 years at implantation on average 4 years and 3 months after operation. Out of 74 prostheses with a minimum observation period of a corresponding length 14 had been implanted in males under 70 years of age.

Resorption of the calcar femoris preceded fracture of the stem. All the fractured stems had been implanted in a varus position. Tissue reaction to wear products might have contributed to bone resorption.

Even if a new design may reduce the tendency to fracture of the stem of the prosthesis, it is emphasized that varus position of the stem should be avoided.

LATE INFECTIONS AFTER TOTAL HIP REPLACEMENT

Olav Reikerds

Kronprinsesse Marthas Institute, Oslo

Infection is the most serious complication of total hip replacement. We have reviewed 293 operations with a mean follow up of 4.2 years. There were five infections 1-4 years after the operation. Three of these were the low virulent type combined with loosening of the prosthesis and the presence of staphylococcus albus. Two young patients 29 and 33 years respectively, with Bechterew's disease got a virulent infection 2 and 3 years after the operation. One was infected with β haemolytic streptococcus following an erysipelas of the leg. The other was infected with staphylococcus aureus in connection with extraction of a molar tooth. It is suggested that both were infected from haematogenous seeding.

THE

*for Steinar Rangstad, Anders Mølster,
Willy Haukeland & Antti Alho*
Haukeland Hospital, Bergen

The Ender method consists of insertion of round flexible condylocephalic intramedullary nails. 104 patients were reviewed. The median age was 77 years and 80 per cent were older than 70 years. Concomitant diseases were found in 73 per cent.

The follow up showed good functional results. There was a tendency for shortening to occur more than 2 cm in 15 per cent of the patients. External malrotation of more than 20° was observed in 15 per cent of the patients. Towards the end of the series, with awareness of this problem, the malrotation decreased.

The Ender method has advantages, with a short operation time, minor operative trauma, and early mobilization and weight bearing. Because of some rotational instability the method should be reserved for patients older than 65-70 years.

FRACTURES OF THE NECK OF THE FEMUR TREATED WITH VON BAHR SCREWS

*Anders Mølster, Odd Søreide &
Tor Steinar Rangstad*
Haukeland Hospital, Bergen

The material consists of 103 patients with displaced, intracapsular fractures of the neck of the femur treated with von Bahr screws. Early weight bearing was allowed.

At the 1-year follow-up, 18 patients had mechanical failure, 68 were healed with six diagnosed aseptic necroses of the head of the femur. Eleven patients were dead, and the remaining did not attend the follow up examination. Excellent or good results were achieved in 80 per cent in the healed fracture group (Stinchfield classification system).

There was a highly significant correlation between operative result and late result. Exact reduction and a slight valgus position, as well as a parallel screw position, with the distal screw lying on the calcar, led to favourable late results. The degree of primary dislocation (Garden 2-4) did not correlate with the incidence of delayed healing or mechanical failure. The number of cases with aseptic necrosis was small, but five of the six had primary dislocation graded as Garden 4, though all six had an operative result graded as excellent or good.

OPERATIVE TREATMENT OF COMMINUTED FRACTURES OF THE LOWER END OF THE HUMERUS

Pål Benum & Sverre Sjørsen
Ullevål Hospital, Oslo

The results after osteosynthesis of 12 severely dislocated comminuted fractures, stabilized with screws, pins and/or plates, are reported. The transolecranon approach was used in 10 patients. Flexion was excellent in three, good in four, and fair in three patients. One suffered from pain after healing of the fracture. Two patients, operated with an inverted Y incision through the triceps aponeurosis, dislocated and ended up with poor mobility.

It is concluded that exact reduction and stable fixation of highly dislocated, comminuted fractures of the lower end of the humerus should be performed with a transolecranon approach. However, excellent operative conditions are mandatory.

Clinical pulmonary signs were scanty. The patient died 5 days after injury.

Autopsy revealed multiple fat emboli in the lungs and brain and small haemorrhagic infarcts in all parts of the brain. Fat embolism syndrome after a tibial fracture is rare and especially so in this age group.

AVULSION OF THE ISCHIAL TUBEROSITY

Anders Dahle

Regional Hospital in Trondheim, Trondheim

Four patients with avulsion of the ischial tuberosity, two boys and two girls, are reported. The main symptom was pain in the buttock which started at the age of 12 to 15 years. Three had been injured during sports activities and in one patient the symptoms occurred after rowing without other trauma. The mechanism of the pain could in all patients be explained as overstretching of the hamstrings.

Two patients with complaints lasting 3 and 7 years respectively, were operated upon. They had a non union of the apophysis which was removed with good results.

Slavanger, May 12th-14th, 1977

EXPERIENCES WITH A STERILE OPERATING CHAMBER

Sverre Skeie

Sandnes Hospital, Sandnes

In September 1974 a sterile operating chamber was installed at this hospital. Up to November 1976 324 total hip replacement operations *ad modum* Charnley were performed in the chamber. So far there have not been any primary or secondary signs of infection or loosening of the prostheses.

The sterile operating chamber has furthermore been in daily use for other types of bone operations.

At each operation two Petri dishes of blood agar have been placed on the floor of the chamber. For 1140 observations the growth has been 0.6 colonies per dish per hour.

PREVENT IFICATION

Trondheim

Fifty one operated hips in 73 patients were evaluated 3 months after operation. There were two main groups: 54 hips in patients not given IMC and 27 hips in patients given 25 mg IMC, 3 times daily, the first 4 weeks postoperatively. The group without IMC showed a greater fre-

quency of high grade ossification while low grade ossification was equally frequent in the two groups. In the former group there were no signs of ectopic ossification in only 14 hips i.e. 26 per cent. In comparison no ossification was seen in 17 hips in patients given IMC, i.e. 63 per cent.

It is concluded that IMC significantly prevents postoperative ectopic ossification following total hip replacement.

INDOMETHACIN HIP'S

Helge Rønningen & Norvald Langeland

Sophies Minde Orthopaedic Hospital, Oslo

The course of osteoarthritis in 294 hips of 186 patients was evaluated by examining their radiographs. The development of the disease in patients treated with indomethacin was compared with that in a control group. In the indomethacin group the disease progressed more frequently and in some parameters the progress seemed more severe. The results support previous reports indicating that indomethacin might have a deleterious effect on osteoarthritic hip joints. Some possible explanations for this adverse effect of indomethacin treatment are briefly discussed.

CONTROLLED INDUCED HYPOTENSION IN HIP SURGERY

U. t. Khalid Kahn & Ole Dankert Lunde

Sandnes Hospital, Sandnes

The pharmacological basis, the technique, the indications and contraindications for the use of induced controlled hypotension were given. Fifty patients had a total hip replacement arthroplasty *ad modum* Charnley. 25 under controlled hypotension, 25 under normotension.

In the former group the perioperative haemorrhage was reduced to a fifth compared with the normotension group. The operative time was reduced by 15 per cent and the need for blood transfusions reduced by 50 per cent. A comparative study of nine bilateral cases gave identical results. There were no postoperative complications recorded in either of the groups.

FRACTURE OF THE FEMORAL STEM AFTER TOTAL HIP REPLACEMENT

Pål Benum

Regional Hospital in Trondheim, Trondheim

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Resorption of the calcar femoris preceded fracture of the stem. All the fractured stems had been implanted in a varus position. Tissue reaction to wear products might have contributed to bone resorption.

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FURTHER EXPERIENCE IN THE TREATMENT OF PER AND SUBTROCHANTERIC FRACTURES OF THE FEMUR BY THE ENDER METHOD

Tor Steinar Raugstad, Anders Mølster

Willy Haukeland & Antti Alho

Haukeland Hospital Bergen

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It is concluded that exact reduction and stable fixation of highly dislocated comminuted fractures of the lower end of the humerus should be performed with a transolecraneal approach. However excellent operative conditions are mandatory.

COMMINUTED FRACTURES IN THE DISTAL PART OF THE RADIUS TREATED WITH EXTERNAL FIXATION AD MODUM HOFFMANN

Ulf Stungaard

Aker Hospital Oslo

Comminuted fractures of the distal end of the radius have a tendency to heal with shortening when treated with reduction and plaster cast

Five patients treated with external fixation *ad modum* Hoffman with two screws in the second metacarpal bone and two screws in the radius proximal to the fracture are reported

The patients tolerated this treatment well finding it more comfortable than plaster (all had been first unsuccessfully treated with plaster)

SPIRAL FRACTURES OF THE TIBIA TREATED WITH PERCUTANEOUS WIRE CERCLAGE

Anders Volster

Haukeland Hospital Bergen

The preliminary results of Goeltze's percutaneous application of wire cerclage followed by functional plaster for oblique and spiral fractures of the tibia are reported

Seven patients were operated on and an exact anatomical position was achieved without primary complications. None redislocated and so far four have been allowed weight bearing after 10-16 weeks. The wires were removed after 12-23 weeks

Percutaneous cerclage makes plaster treatment easier and safer without a tendency for shortening to occur and permits early ambulation. It should only be used for fractures with a fracture line longer than two tibia diameters

RECONSTRUCTION OF THE LATERAL LIGAMENTS OF THE ANKLE JOINT AD MODUM STOREN

Tor Finn Denstad & Ludvig Fjeld Solheim

Martina Hansens Hospital Sandvika

Reconstruction of the lateral ankle ligaments *ad modum* Storen using the medial one third of the Achilles tendon as a nourished transplant is probably little known [*Acta chir scand* (1959) 117:501-509]

Eighteen patients previously operated on using this technique answered a questionnaire. Seventeen had a stable joint and were satisfied due to a new injury, one was reoperated using Evans' tenodesis operation. Active athletes were in full training 3-4 months after the operation. Late residual symptoms (pain, reduced mobility, swelling) were few

REPAIR OF RUPTURES OF THE CUFF OF THE SHOULDER JOINT USING A POSTERO SUPERIOR ACROMION SPLITTING APPROACH

Einar Sudmann

Regional Hospital in Tromsø Tromsø

Two patients with complete rupture of the shoulder cuff have been operated on using a postero superior approach *ad modum* Debye et al. [*J Bone Jt Surg* (1965) 47 B:36-42]. The approach proved very adequate permitting easy mobilization of the supraspinatus muscle in one case and making the repair of the tear possible without undue tension

AN EVALUATION OF THE PROSTHESIS SERVICE FOR LOWER EXTREMITY AMPUTEES IN SANDNES

Else Marie Høyem

Sandnes Hospital Sandnes

A follow up examination of 82 patients (average age 60½ years) fitted with a prosthesis showed that a surprisingly large number of the patients (95 per cent) were using their prosthesis but 62 per cent of them had more or less serious problems now and then. Half of the patients were not satisfied with the service provided

Indications for amputation were vascular diseases in 34, injuries in 31 and other causes in 17

It is concluded that it is necessary to provide more adequate information for patients and relatives, more time should be spent for fitting and rehabilitation, there should be more frequent visits from the orthopaedic technician and a regular follow up of the amputees. Treatment at rehabilitation centres would be preferable

GIANT CELL TUMOUR OF BONE TREATED WITH AUTOGENOUS BONE GRAFT

Terje Terjesen

Regional Hospital Trondheim

Most giant-cell tumours of bone are invasive and aggressive in their behaviour with a recurrence rate in large series of about 40 per cent. A 30 year old woman with a giant cell tumour in the distal end of the radius was treated by en bloc resection and reconstructed with an autogenous bone graft from the upper third of the fibula

Solid union between the graft and the radius occurred. The functional result was satisfactory. She had no pain in the wrist and a good grip although the range of mobility in the wrist

Joint and rotation of the forearm was considerably reduced

GRISSELS SYNDROME

Kjetil Harbo

Sandnes Hospital Sandnes

Two girls 4 and 7 years of age respectively developed painful torticollis the youngest after an upper respiratory tract infection and the oldest after an operation for cleft lip and palate. Radiological examination showed in the youngest patient a subluxation between C-II and C-III and in the other, an atlantoaxial subluxation.

Both patients were treated by the double mattress technique for 4 and 8 weeks and were further immobilized in a Minerva jacket for 8 and 12 weeks respectively. The subluxation was reduced in both cases during extension treatment. Both girls have completely recovered. The treatment started in one case 1 month, in the other 6 months after the onset of symptoms.

RESTORATION OF THUMB OPPOSITION

Gisle Uppheim

Kronprinsesse Marthas Institute Oslo

A total of 110 tendon transfers for restoration of thumb opposition were reviewed (sequelae to poliomyelitis 61 trauma 30). The results were good in 74 fair in 25 and poor in 11 cases. The higher proportion of failures in the poliomyelitis group can be explained by the use of muscles which were too weak.

Distal insertion *ad modum* Bunnell (18 cases) gave a better result than did insertion *ad modum* Riordan (10 cases). Of eight extensor muscle transfers six had a good result. Of 97 flexor sublimis transfers 23 developed a significant flexion contracture at the proximal interphalangeal joint of the donor finger while three developed a swan neck deformity.

OPERATIVE TREATMENT FOR POST TRAUMATIC STIFFNESS OF THE KNEE JOINT

Per Siewers & Helge Fjermoes
Central Hospital in Kristiansand
Kristiansand S

Five adult patients who had severe stiffness of the knee joint following trauma, in or near the joint were treated by operation when no further spontaneous improvement was expected.

The operative procedures were based mainly on Thompson's quadricepsplasty. The average gain in active flexion was 60° a highly satisfactory result.

WAGNER'S METHOD OF LIMB LENGTHENING

I Bjerkreim & Langeland & H Rønningen
Sophies Minde Orthopaedic Hospital Oslo

A short survey of indications for and complications in leg lengthening was given. The Wagner device for limb lengthening was used in a 14 year old girl height 150 cm with a congenital 6 cm shortening of the left femur. After 3 weeks of distraction the pins had bent slightly and a varus angulation developed. Equalisation was predicted at 6 weeks. The proximal pin holder however slipped on the distraction bar and half of the correction was lost. After adjustment and resecuring of the pin holder limb length equalisation was attained at 12 weeks. Osteosynthesis using a strong metal plate and cancellous bone from the iliac crest was performed. The varus angulation could be corrected and the Wagner device was used as additional fixation for another 4 weeks. Because of considerable reduction in knee flexion to 30° the pins were removed and the knee flexion rapidly normalized.

A follow up radiological examination showed increasing bone healing.

LENGTHENING OF THE FEMUR AD MODUM WAGNER

Einar Sudmann

Regional Hospital in Tromsø Tromsø

In a female patient aged 17 years with a leg length discrepancy of 7.5 cm the femur was lengthened 7.5 cm in 0.15 cm daily increments after a transverse mid femoral osteotomy. The length so obtained was retained by a plate applied laterally and blocks of bone allografts wedged in between the bone ends. The patient with the Wagner lengthening device attached was allowed out of bed on crutches. No complications were encountered.

NON UNION OF THE CLAVICLE

Arvid Hugberg

Sandnes Hospital Sandnes

Factors predisposing to development of post traumatic non union of the clavicle and indications for operative treatment were discussed. Four patients treated with intramedullary nailing using Rush pins and transplantation of bone chips from the iliac crest were reported. The results were good.

THE USE OF BONE CEMENT FOR
FIXATION OF FRACTURES IN PATIENTS
WITH MYELOMATOSIS

Bjørn Samstad

Regional Hospital Trondheim

Bone cement was used for fixation of fractures in two patients with myelomatosis. In an 80 year old woman with a spontaneous fracture of the femur which crossed the lesser trochanter the entire medulla of the proximal fragment was filled with bone cement prior to fixation of the fracture with an angled nail plate. There were no postoperative complications and the patient walks without support.

In a 56 year old man a spontaneous fracture of the acetabulum was treated with insertion of a Muller total hip prosthesis. The bone defect was filled with bone cement prior to the insertion. There were no postoperative complications. Four months later he was admitted with an identical fracture of the other hip which was treated in exactly the same way with a similar satisfactory result.

There have been no clinical or radiological signs of recurrence of the local process 1 year postoperatively in either patient.

ELECTRICAL STIMULATION IN DELAYED UNION OF LONG BONES

K P SRIVASTAVA & A K SAXENA

SN Medical College Agra India

The role of electricity in the promotion of fracture union of long bones in human beings requires further investigation. An electric stimulator was devised through which 15 μ A current was applied to the fractured long bones of 20 patients with delayed union. The best results were obtained in cases where the negative electrode was introduced at the fracture site and the positive electrode was placed proximal to the fracture area. In 90 per cent of cases treated by different methods in this series union occurred within an average period of 9½ weeks. The rate of infection following introduction of the electrodes for electrical stimulation was 20 per cent.

Key words: delayed union, electrical stimulation, human beings.

Accepted 20 vii 77

Friedenberg & Brighton (1966) measured the resting potentials of fractured bone in rabbits. They found that the metaphysis had a negative potential in relation to the diaphysis. Following fracture of the shaft of the tibia, the diaphysis became negative in relation to the epiphysis and the metaphyseal potential also became more negative. The negativity of the diaphysis remained until the fracture united, after which the potential returned to normal.

Bassett et al (1964) implanted iridium electrodes on dog femurs and observed the formation of extensive callus at the cathode within a period of 15 days using a 10-100 μ A current. An increased number of young mesenchymal cells and osteoblasts were found around the cathode. At the positive electrode a brownish material consisting of denatured protein was found.

Brighton & Alfred (1972) attributed

the increased callus formation to the increased alkalinity and the low oxygen tension in the cathode area. He observed that the oxygen tension remained low during the phases of healing and later returned to normal when the fragments consolidated. Low oxygen tension led to calcium release from the mitochondria of cartilage cells and it initiated the pluripotential cells to differentiate into osteoblasts and chondroblasts.

Friedenberg et al (1970) found that a 20 μ A was the optimum strength of the current. Bone destruction occurred when the current was raised to 40-50 μ A. Gieszynski (1963) observed that a positive potential increased the breaking strength of rabbit bone, while a negative potential did not improve healing. Friedenberg (1971a) and Lavine et al (1971) reduced the period of immobilization of fractures in rabbits by electrical stimulation.

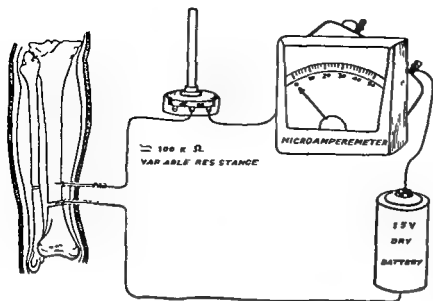


Figure 1 Diagram of the electrical circuit for electrical stimulation of bone

Even in human beings electrical stimulation has been used successfully. Friedenberg (1971b) achieved union in a case of non-union of the medial malleolus. Levine et al (1972) reported union in a case of congenital pseudarthrosis of the tibia. Jorgensen (1972) has published the largest series having employed electrical stimulation in 24 cases of tibial fractures. He used a direct current of 20–100 μ A in addition to altering current and found that the consolidation time was reduced by 30 per cent. Soft tissue necrosis and infection occurred at the anode in a few cases.

METHODS

Stimulator The electrodes were made from 28 gauge stainless steel wire insulated with polythene tube which was sealed over the wire the ends being left bare. A trophine and cannula were used for inserting the electrodes.

The circuit was made up of 28 gauge insulated copper wire, 15 V dry battery, 0–100 K Ω variable resistance (used in radio sets as a volume regulator), microampere meter with a scale of 0–50 μ A.

The variable resistance and the microampere meter were connected in series with the positive end of the battery while the negative end was connected directly to the electrode using 28 gauge insulated copper wire (Figure 1). The whole of the circuit except the microampere



Figure 2 Microampere meter connected to the electrical circuit placed inside the plaster

meter was fixed to the plaster (Figure 2) The microampere meter was used to check the strength of current flowing in the circuit The current strength was kept constant by altering the resistance during the periodical checkups

PATIENTS

In the present series 20 cases of delayed union were studied and followed up (Table 1)

Table 1 Electrical stimulation in 20 cases of delayed union

Bone	No of patients	Percentage
Tibia	16	80
Humerus	1	5
Radius and ulna	3	15

All the patients had pain elicited by bending stress near the fracture site and 11 of them had slight mobility of the fragments Only cases of delayed union with a minimum of 5 months duration and with no radiological evidence of established non union were included in the series (Table 2)

Table 2 Interval between the time of injury and the beginning of electrical stimulation

Interval (months)	No of patients	Percentage
Up to 3	6	30
5-10	10	50
11-15	2	10
16-20	nil	—
Above 20	2	10

Four patients had a mild infection before starting the electrical stimulation

RESULTS

The patients were divided into three groups (Table 3 and Figure 3) 15 μ A current was given in each case The preliminary assessment was made after 8 weeks of electrical stimulation

Group A In all four patients the electrodes were placed with one proximal and one distal to the fracture site All united in the course of 8 to 12 weeks

Group B In this group, the positive electrodes were inserted proximal to the fracture site and the negative electrodes were inserted at the fracture site Out of 12 patients treated in this group, 10 united within 8 weeks In one, the electrodes were removed too early as a result of which the plaster immobilization had to be prolonged for another 4 weeks increasing the healing time to 12 weeks The remaining fracture did not unite because the patient started weight-bearing too early Bone grafting had to be performed in this case

Group C In four patients of this group the negative electrodes were inserted at the fracture site while the positive electrodes were left in the adjacent soft tissues One united within 8 weeks, two needed further stimulation for 2½ weeks and one failed to unite due to gross infection

Out of a total of 20 cases, 18 united within an average period of 9¼ weeks of electrical stimulation, while two cases failed to unite

The period of hospital stay was 3-30 days in 18 cases Two cases had to stay for longer periods due to infection

Complications

Infection Out of 20 cases, four became infected One of these failed to unite due to the infection

Loosening of electrodes In four cases the electrodes were pulled out while dressings were being changed, they were reinserted

Metallic corrosion of electrodes The corrosion occurred at the anode, leading to longitudinal splitting and occasional breaking of the wire

In a few cases the uninsulated part of the wire turned black.

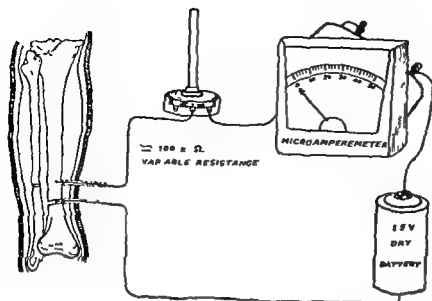


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SITE OF PLACEMENT OF ELECTRODES IN DIFFERENT GROUP OF CASES

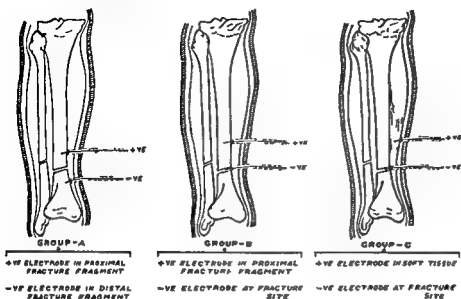


Figure 3 Diagram showing the placement of the electrodes in the three groups (A, B, C)

Table 3 Results of electrical stimulation

Group	No of cases	Average strength of current (μ A)	Duration of electrical stimulation (weeks)	Results		
				Radiological union in 8 weeks	Radiological union in 12 weeks	No union within 12 weeks
A	4	15	8	—	4	—
B	12	15	8	10	1	1
C	4	15	8	1	2	1

DISCUSSION

The present study was based on clinical as well as radiological findings. It demonstrates that union may result from electrical stimulation in otherwise indolent cases of delayed union. The negative potentials were induced in a relatively inactive area at the site of delayed union in order to cause acceleration of cellular activity. In 90 per cent (18/20) of the cases treated in the various groups in this series union was achieved in an average period of 9¼ weeks.

Union in group A cases in this series confirmed the findings of Lavine et al (1972) and Jorgensen (1972) but at the same time contradicted the findings of Friedenbergl (1971b), who failed to ob-

tain acceleration of union in patients comparable with those in group A of this series. This discrepancy of results could be due to the short period of electrical stimulation used in the cases described by Friedenbergl. Although union was obtained in all group A cases of this series, it took a longer time (12 weeks) than in B and C groups (8 weeks).

Results were found to be better in cases, where the cathode was placed at the fracture site (groups B and C). Best results were observed in group B, where the positive electrode was inserted proximal to the fracture site and the negative at the fracture site itself. This is in agreement with the findings of Friedenbergl. The strength of current used in this

series (15 μ A) in all cases gave satisfactory union with no unfavourable effects on bone substance.

The infection rate in this series was 20 per cent (4/20). Two of these were superficial. Osteoporosis of the distal tibial fragment as reported by Jorgensen (1972) was not seen in this series. The feeling of warmth at the site of introduction of the electrodes was noted in a few cases in the initial stages.

Conclusions

- 1 Negative potentials can promote the union of fractures in cases of delayed union.
- 2 In 90 per cent of cases treated by various stimulation methods union occurred in an average period of 9¼ weeks.
- 3 The best results were obtained when the negative electrodes were placed at the fracture site and the positive electrodes in the proximal fragment.
- 4 The morbidity and hospitalization period was considerably reduced.

REFERENCES

- Bassett C A L, Pawluk R J A & Becker R O (1961) Effect of electric current on bone in vivo. *Nature (Lond)* 204 652-654.
- Brighton C T & Alfred H K (1972) Oxygen tension of healing fractures in rabbits. *J Bone Jt Surg* 54 A 323-332.
- Cieszyński T (1963) Studies on the regeneration of osseal tissue II Treatment of bone fractures in experimental animals with electric energy. *Arch Immunol Ther exp (Warsz)* 11 199-217.
- Friedenberg Z H & Brighton C T (1966) Bioelectric potentials in bone. *J Bone Jt Surg* 49 A 915-923.
- Friedenberg Z B, Brighton C T, Andrews E T, Smolenski B I & Pearl B W (1970) Bone reaction to varying amounts of direct current. *Surg Gynec Obstet* 131 894-899.
- Friedenberg Z H, Roberts P G Jr, Didizian N H & Brighton C T (1971a) Stimulation of fracture healing by direct current in the rabbit fibula. *J Bone Jt Surg* 53 A 1400-1408.
- Friedenberg Z B, Harlow M C & Brighton C T (1971b) Healing of non union of medial malleolus by means of direct current. A case report. *J Trauma* 11 883-885.
- Jorgensen T E (1972) Effect of electric current on the healing time of crural fractures. *Acta orthop scand* 43 421-437.
- Lavine L S, Lustrin I, Shamos M H & Moss M L (1971) The influence of electric current on bone regeneration in vivo. *Acta orthop scand* 42 305-314.
- Lavine L S, Lustrin I, Shamos M H, Rinaldi R A & Liboff A R (1972) Electric enhancement of bone healing. *Science* 175 1118-1120.

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SITE OF PLACEMENT OF ELECTRODES IN DIFFERENT GROUP OF CASES.

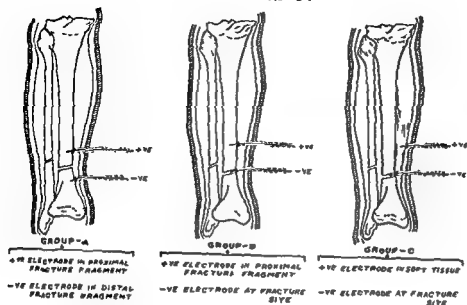


Figure 3 Diagram showing the placement of the electrodes in the three groups (A B C)

Table 3 Results of electrical stimulation

Group	No of cases	Average strength of current (μ A)	Duration of electrical stimulation (weeks)	Results		
				Radiological union in 8 weeks	Radiological union in 12 weeks	No union within 12 weeks
A	4	15	8	—	4	—
B	12	15	8	10	1	1
C	4	15	8	1	2	1

DISCUSSION

The present study was based on clinical as well as radiological findings. It demonstrates that union may result from electrical stimulation in otherwise indolent cases of delayed union. The negative potentials were induced in a relatively inactive area at the site of delayed union in order to cause acceleration of cellular activity. In 90 per cent (18/20) of the cases treated in the various groups in this series union was achieved in an average period of 9¼ weeks.

Union in group A cases in this series confirmed the findings of Lavine et al (1972) and Jorgensen (1972) but at the same time contradicted the findings of Friedenbergs (1971 b), who failed to ob-

tain acceleration of union in patients comparable with those in group A of this series. This discrepancy of results could be due to the short period of electrical stimulation used in the cases described by Friedenbergs. Although union was obtained in all group A cases of this series, it took a longer time (12 weeks) than in B and C groups (8 weeks).

Results were found to be better in cases, where the cathode was placed at the fracture site (groups B and C). Best results were observed in group B, where the positive electrode was inserted proximal to the fracture site and the negative at the fracture site itself. This is in agreement with the findings of Friedenbergs. The strength of current used in this

It might, therefore, be of value to have an easy and reproducible method for counting osteoclasts per surface area of bone. The determination of active and inactive resorption surfaces and bone formation surfaces used earlier is more difficult and perhaps not so useful when testing the hypotheses mentioned. Data in the literature concerning the normal number of osteoclasts are sparse and vary greatly and the number has been decided per area of the section (e.g., Bordier & Tunchot 1972, 0.37/mm², and Ellis & Piar 1973, 0.01-0.03/mm²). In this paper we have tested a modified method for counting osteoclasts both per area of section and per surface of bone area in normal individuals compared with patients with osteoporosis and patients with chronic nephropathy undergoing haemodialysis.

MATERIAL AND METHODS

The control group consisted of 51 men and 36 women (10-90 years) who had died suddenly following cardiac arrest, accident or suicide and had been brought to the Forensic Department for autopsy. A wedge-shaped sample was taken from the iliac crest just dorsal to the iliac spine.

The osteoporosis group consisted of 48 women (44-71 years) with radiological and clinical signs of spinal osteoporosis. The nephropathic group consisted of 91 patients, all of them undergoing haemodialysis. Details of the nephropathic patients with data relating to the state of the disease and laboratory examinations will be presented in another paper. In the present paper we have only used the biopsies for testing the osteoclast counting method.

A 15 × 3 mm cylindrical sample was obtained from the patients with a motor-driven slow moving drill according to Burckart. The sample was taken vertically about one cm dorsal to the iliac spine.

The samples were fixed in formalin, dehydrated in alcohol, chloroform and embedded in methacrylate without previous decalcification and finally cut into sections (3-7 µ). The sections were stained according to Goldner (1955).

The margins of the sections were taped in order to obtain a straight line rectangular area of trabecular bone. All osteoclasts in this area

were counted (per mm²) with 40 × objective and 10 × eyepiece magnification. The osteoclasts were identified by their light pink, often vacuolar, cytoplasm and the distinct nucleoli. Only osteoclasts with two or more nuclei and in contact with the bone surface were counted.

In our evaluations of trabecular and osteoid surfaces we used an objective magnification of 13 × and an eyepiece magnification of 10 ×. We used a grid with wave formed lines in the eyepiece as described by Schenk et al (1969). We counted the number of intersections between the grid lines and trabecular and osteoid surfaces in 25-30 fields of every specimen. In order to make the whole procedure simpler we counted only the number of intersections without calculating the trabecular circumference area as in Schenk et al (1969). This latter calculation does not give any further useful information beyond the counted data and our main interest is to present the number of osteoclasts relative to the remaining bone tissue which can be used to compare groups of specimens with each other.

RESULTS

The number of osteoclasts per section area and the number relative to the bone surface area in normal individuals, in osteoporotics and in haemodialysis patients are seen in Table 1. The mean of the absolute and the relative number of osteoclasts is the same in normal and osteoporotic individuals, in haemodialysis patients almost ten times higher. The frequency distribution of osteoclasts per mm² section in per cent of the total number of normal individuals, osteoporotics and haemodialysis patients, respectively, is shown in Figure 1. It seems clear that 99 per cent of the normal individuals have between 0-0.1 osteoclasts per mm² section. Most (or 90 per cent) of the osteoporotic patients have the same average number of osteoclasts as normal individuals but there is also a small group with between 0.1-0.2 osteoclasts. It is remarkable that so many of the osteoporotic patients (30 per cent) have no osteoclasts at all. Patients

In the haemodialysis patients the osteoclast count/mm² decreased sig-

OSTEOCLAST COUNTING IN CRISTA BIOPSIES

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A description is given of a modified method of counting osteoclasts both per section area and also relative to the remaining trabeculae surface area in crista biopsies. The material consisted of normal individuals, patients with clinical osteoporosis, and patients with chronic renal failure undergoing haemodialysis. The number of osteoclasts in the biopsies from normal and osteoporotic individuals showed a normal distribution with the same mean. In the haemodialysis patients there was a marked skew distribution. In normal individuals, there was a significant decrease in the number of osteoclasts per section area with age, but this was not significant when calculated relative to the bone surface area.

Key words: crista biopsies, osteoclasts, osteoporosis, haemodialysis, renal osteopathy.

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When looking through histological slides from crista biopsies of older normal or osteoporotic humans, an almost total absence of osteoclasts (and osteoblasts) is apparent. Therefore, it is difficult to explain how the bone tissue can disappear with increasing age, especially in postmenopausal women. The periosteocytic resorption described by Belanger (1971) cannot be valid in "idiopathic" osteoporosis since the remaining bone trabeculae always have normal bone density. Jaffe (1972), among others, considers therefore that the osteoclasts do not have an exclusive significance in the development of osteoporosis.

Until the opposite is proven, however, there is reason to consider osteoclasts as

being responsible for bone resorption also in the development of osteoporosis. It is possible that osteoporosis develops very rapidly, mainly in the initial period after menopause, or that some types of osteoporoses proceed stepwise by repeated osteoclast attacks over short periods. In fact, during the last few years some substances producing osteoclastic resorption of bone have been investigated, e.g., OAF (osteoclast activating factor), produced *in vitro* by mitogenic stimulation of lymphocytes (Horion et al 1972) and prostaglandins (Dietrich & Raisz 1975), active, for example, in connection with immune response and inflammatory disease (and malignancy). These and perhaps other substances with similar effect, working over short periods, could explain the apparent defective connection between bone resorption and acting cells.

Financial support was obtained from Herman Järnharfts Stiftelsen and the Swedish Medical Research Council.

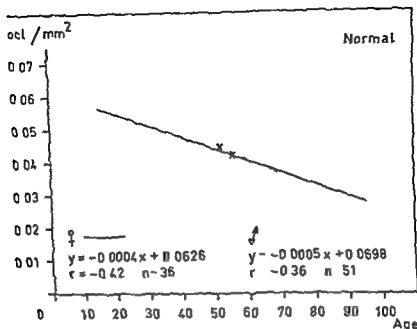


Figure 2 The relation between the number of osteoclasts per mm² section and the age of normal individuals. There is no significant correlation in both sexes. The correlation coefficient for both sexes $r = -0.32$.

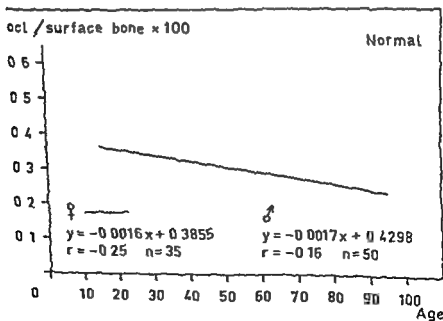


Figure 3 The relation between the number of osteoclasts per surface bone and the age of the normal individuals. There is no significant correlation.

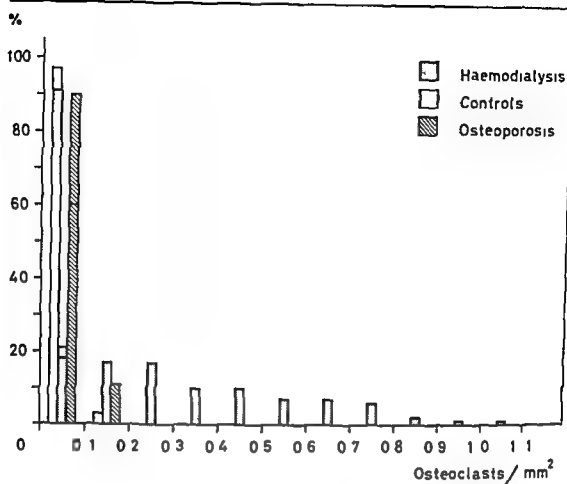


Figure 1 Histogram showing the frequency distribution of the number of osteoclasts/mm² as a percentage of the total number of normal individuals and patients with osteoporosis or haemodialysis. The detached upper parts of the three staples in the 0.01 area represent cases without osteoclasts.

Table 1 The number of osteoclasts per mm² of the section and the number of osteoclasts relative to the bone surface area in the total material. The correlation coefficients for the number of osteoclasts relating to age are also shown.

		Osteoclasts/mm ² section		Osteoclasts relative to bone surf. area	
		Mean and SD	Age regression	Mean and SD	Age regression
Normal	n = 87	0.04 ± 0.02	r = -0.32**	0.003 ± 0.001	r = -0.19
Osteoporosis	n = 48	0.04 ± 0.04	r = -0.19	0.003 ± 0.003	r = -0.23
Haemodialysis	n = 91	0.32 ± 0.26	r = -0.37**	0.024 ± 0.014	r = -0.27*

** = 0.01 > P > 0.001

* = 0.05 > P > 0.01

significantly with age. See Table 1 and Figure 2 (normal individuals). There was no difference between men and women. However, when the osteoclast numbers were divided by the relative bone surface area, the age decrease was no

longer significant for normal individuals, but there was a low significance for the haemodialysis group. See Table 1 and Figure 3 (normal individuals). The correlation between the number of osteoclasts/mm² and the relative bone surface

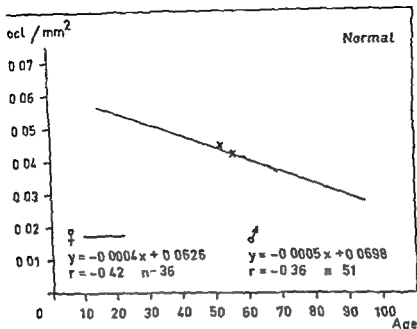


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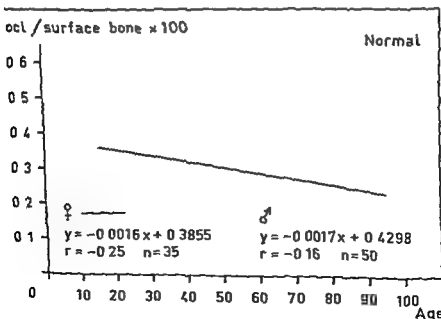


Figure 3 The relation between the number of osteoclasts per surface bone and the age of the normal individuals. There is no longer any significant correlation.

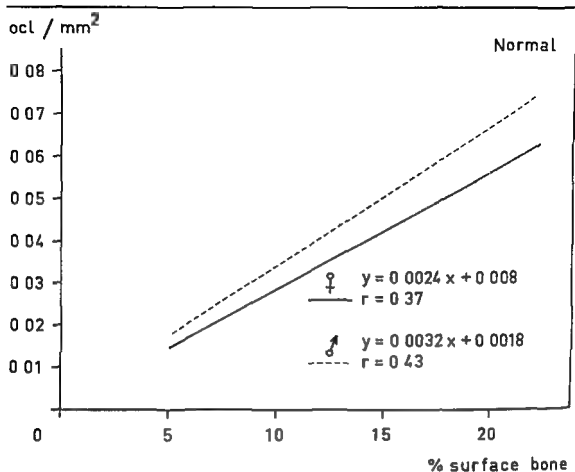


Figure 4 The correlation between the number of osteoclasts counted per mm² section of the slides and the percentage surface area of bone. There is a significant correlation.

area in normal (Figure 4) and dialysis cases was significant. There was, however, no correlation between osteoid surface and the number of osteoclasts/mm².

DISCUSSION

A method for counting osteoclasts in the iliac crest is described which differs only slightly from previous methods. The average number of osteoclasts is very low in sections from normal and osteoporotic iliac crests, and lower than that presented by Bordier & Tunchot (1972). The average osteoclast number in patients undergoing haemodialysis was almost ten times higher, but the frequency distribution, unlike normal and osteoporotic individuals, is quite skew—perhaps in-

dicating different degrees of severity of the disease.

This difference between our normal values and those of Bordier & Tunchot might be due to our not having counted osteoclasts with only one nucleus, either actual uni-nuclear or multinuclear cells cut through one pole. Our way of counting is easier and certainly more reproducible. It is not greatly dependent on the quality of staining.

In the normal group we found a decreasing osteoclast count/mm² of the section with age and no difference between men and women. This decrease is not actual, being due to decreased bone surface, which was also found by Schenk et al (1969). In five cases in the osteoporosis group, we found a large number of osteoclasts (0.102/mm²), out of

keeping with the rest of the group. Most of these osteoclasts were lying close to the surface of the trabeculae without Howships lacunae. We have no information as to whether these patients were suffering from some illness. Thus, we have no explanation for this finding other than it might possibly involve cases where the bone tissue was exposed to an incipient osteoclastic attack.

There was no correlation between the number of osteoclasts and the osteoid surface which supports the hypothesis that osteoclasts resorb the bone tissue intermittently.

REFERENCES

- Belanger L. F. (1971) *Osteocytic resorption. The biochemistry and physiology of bone*. 2nd ed. Ed. Bourne G. H., p. 239-270. Academic Press, New York-London.
- Bordier Ph. J. & Tunchot S. (1972) Quantitative histology of metabolic bone disease. In *Clinics in endocrinology and metabolism* 1. Ed. MacIntyre I., p. 197-215. Saunders & Co. Philadelphia, Pa.
- Dietrich J. W. & Raisz L. G. (1975) Prostaglandin in calcium and bone metabolism. *Clin. Orthop.* 111, 228-237.
- Illis H. A. & Pearl K. W. (1973) Azotaemic renal osteodystrophy: a quantitative study on iliac bone. *J. clin. Path.* 26, 83-93.
- Goldner J. (1933) A modification of the Masson trichromatechnique for routine laboratory purpose. *Amer. J. Path.* 14, 237-243.
- Horton J. F., Raisz L. G., Simmons H. A., Oppenheim J. J. & Vergenhagen S. F. (1972) Bone resorbing activity in supernatant fluid from cultured human peripheral blood leukocytes. *Science* 177, 793-795.
- Jaffe H. L. (1972) *Metabolic degenerative and inflammatory diseases of bone and joints*, p. 367. Urban & Schwarzenberg, München, Berlin-Wien.
- Schenk R. K., Verz W. A. & Müller J. (1969) A quantitative histological study on bone resorption in human cancellous bone. *Acta anat. (Basel)* 74, 44-53.

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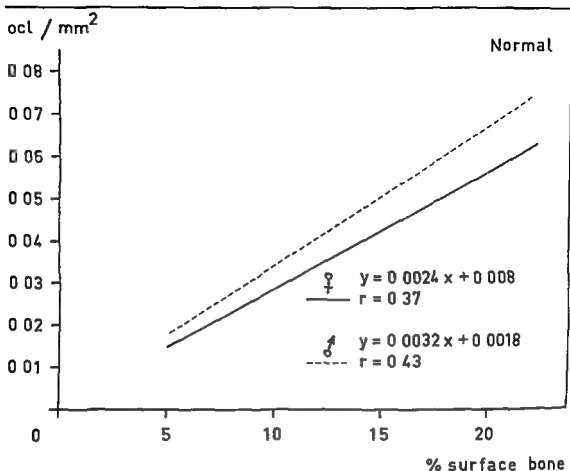


Figure 4. The correlation between the number of osteoclasts counted per mm² section of the slides and the percentage surface area of bone. There is a significant correlation.

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Table 1 Types of implant used

Source of bone and treatment	Method of wash	Whether with marrow
Marrow free iliac cancellous, non decalcified	0.1 M NaH_2PO_4 70% ethanol 0.9% NaCl	With and without With and without With and without
Marrow free, iliac cancellous decalcified in 0.6 N HCl	0.1 M NaH_2PO_4 70% ethanol 0.9% NaCl	With and without With and without With and without
Nil	Nil	Marrow alone

MATERIAL AND METHODS

The experimental design used was similar to that employed previously for evaluating the effect of impregnating fresh and treated allo grafts of cancellous bone with autologous red marrow (Burwell 1964 1966 Wade & Burwell 1977).

The donor bone and methods of treatment

Bone for implantation was taken from both ilia of recently killed rabbits under sterile conditions. The outer cortex was removed and bone marrow was dislodged from the inter trabecular spaces using a forceful jet of sterile water. The ilia were then cut into oval shaped pieces 4 mm long and 2 mm wide, using a stainless steel punch and the remaining blood and marrow cells were flushed out until the pieces looked quite white. Half of the pieces were then decalcified in a cold room (0° to 4° C) with continual agitation in 5 mm of 0.6 N hydrochloric acid (HCl) for 5 h. The decalcified and the non decalcified bone were washed twice in one of three solutions: 0.1 M (isotonic) sodium dihydrogen phosphate buffer at pH 7.4 70 per cent ethyl alcohol or 0.9 per cent sodium chloride. Wash solutions were decanted and the bone stored each piece in a numbered sealed container by freezing to 20° C.

The preparation and implantation of the treated combined myelogenous grafts

The recipients were 42 adult female rabbits under anaesthesia. Small pouches were opened between the oblique muscles of the anterior abdominal wall and a single graft was inserted into each pouch. In order to standardize the host response to each type of implant used 13 implants were inserted into each animal. The types of implant used included iliac bone marrow alone and in the form of combined myelo-

osseous grafts, the marrow being aspirated from a femur of the recipient immediately before implantation. Table 1 shows the types of implant used. As a control a single autograft of red marrow was inserted into a separate pouch.

Three animals were killed at daily intervals up to 14 days after implantation.

Retrieval of grafts and preparation for examination

Animals were anaesthetized and killed by intracardiac vascular perfusion with glutaraldehyde through a carotid arteriotomy. The anterior abdominal wall was removed, pinned on a cork board and fixed by immersion in a 2.5 per cent glutaraldehyde solution. After fixation the abdominal wall was subjected to high definition radiography. Each graft site was then cut out in blocks of about 1 cm square, decalcified and prepared for histological examination staining 8 µm sections with haematoxylin and eosin. No attempt was made to quantitate the amount of bone which formed as had been done previously (Wade & Burwell 1977).

RESULTS

Radiological studies

All 252 calcified implants were detected. One hundred and twenty-six decalcified grafts implanted alone did not produce radiological evidence of (re-) calcification.

Decalcified allografts implanted combined with autologous marrow showed evidence of calcification from the eighth day onwards. This was small in quantity and in the form of scattered specks (Figure 1).

OSTEOGENESIS AFTER BONE AND BONE MARROW TRANSPLANTATION

II. The Initial Cellular Events Following Transplantation of Decalcified Allografts of Cancellous Bone

SIDNEY NADF

Department of Surgery, The University of Sydney, and Raymond Purves Research Laboratories, The Royal North Shore Hospital of Sydney, Australia

An experimental study was done in rabbits to investigate the fate of allogeneic iliac cancellous bone, both non-decalcified and decalcified with hydrochloric acid, transplanted to a muscular site for up to 14 days. Some of the treated allografts were impregnated with autologous bone marrow cells, obtained from the femoral medulla by aspiration, and each was compared with allografts alone. Combined myelo-osseous grafts produced bone after 7 to 8 days implantation, as did marrow autografts alone. In addition non-decalcified implants stimulated the production of multinucleated giant cells. Three different types of wash solution were used but these did not influence the cell population seen, nor the new bone formation. It is concluded that the critical events in bone formation after transplantation occur less than 8 days after the transplantation and that marrow cells have osteogenic capacity. This has relevance to the clinical aspects of bone grafting.

Key words: bone, bone transplantation, bone marrow cells, bone cells

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It has previously been shown by Nade & Burwell (1977) that decalcified iliac cancellous bone, impregnated with autologous bone marrow and grafted to a muscular site in rabbits, formed new bone by 14 days after implantation. Also bone marrow autografts *alone* did this. However, decalcified cancellous bone allografts, without bone marrow, produced, on some occasions, very small amounts of new bone but not until 4 weeks after implantation. These findings were at variance with those of Urist's group (Urist et al 1967) who used cortical bone from the femoral diaphysis in various species and

washed the bone in several different ways after decalcification with hydrochloric acid.

In this paper are reported the morphological findings after implanting hydrochloric acid-decalcified allogeneic iliac cancellous bone, washed in three different ways, and impregnated with autologous bone marrow into the anterior abdominal wall of rabbits for periods of up to 14 days. The critical events leading to osteogenesis take place during this time period.

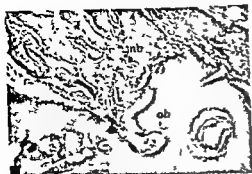


Figure 3 Photomicrograph of HCl decalcified phosphate washed allogeneic iliac cancellous bone implant combined with autologous marrow 12 days after insertion. The newly formed bone (nb) containing osteocytes and lined by osteoblasts is easily distinguished from the non viable implant (ob) (Haematoxylin and eosin $\times 54$)

being recognisable as such until bone had appeared. New bone stained slightly more purple and had osteocytes in lacunae and surrounding matrix (Figure 3). A so called basophilic cement line formed a line of demarcation in some non decalcified implants. Without the presence of a marrow autograft, no newly formed bone, nor osteoblasts were seen. In the 42 marrow autografts inserted alone these features were first seen on the seventh or eighth day after implantation and when combined with any allogeneic bone implant bone did not appear before the eighth day. The pattern was not altered by the method of washing the bone.

d) *Multinucleated giant cells*. These were not seen in marrow autografts nor around bone which had been decalcified before implantation. In the 252 non decalcified implants they first appeared about 6 or 7 days after grafting while in the combined grafts (non decalcified) they were first noticed after 8 days with ethanol washed implants, 12 days with saline washed and were seen at various times in phosphate washed implants. The significance of these differences is not clear however these cells were always

seen about extremities of the implant, and usually in Howship's lacunae.

DISCUSSION

The stimulation of osteogenesis and the identification of cells which contribute to the synthesis of bone matrix have been studied for over three centuries. The considerable variation in findings reported has been due to the animal species used, the interpretation of histology, the technical differences in laboratories and the acceptance of conclusions from statistically insignificant figures.

In the interpretation of previously described work, one must be careful if one accepts the criterion of nuclear staining of osteocytes as indicating cell viability, for the findings of this study as well as of Yoshiki (1962) and Burwell (personal communication 1970) show that such a stain in non decalcified stored bone may be retained for up to 7 days, when the cells are by all accepted criteria non viable.

Previous studies (Nade 1970, Nade & Burwell 1977) have failed to confirm the findings of Urist's group (Urist et al 1968) that HCl decalcified allografts of bone implanted into an intermuscular site evoke the production of newly formed bone presumably by the process of induction. One variable was the method by which the bone was washed after decalcification. This study shows that the cellular response, in the rabbit, is not influenced by the use of sodium chloride solution 70 per cent ethanol or an isotonic phosphate buffer. Admittedly, Urist's group have used diaphyseal cortical bone while this study has used iliac cancellous bone; however, Cummine & Nade (1977) showed that the cellular response around these two types of bone is not different (in the guinea pig).

The findings of earlier reports have been confirmed and have led to the conclusion that fresh bone marrow auto



Figure 1 Radiograph of implant site in abdominal wall 12 days after insertion of HCl-decalcified (radiolucent) cancellous iliac allograft combined with autologous marrow. Scattered specks of calcification are seen, which on histological examination (Figure 3) were due to new bone formation (magnification $\times 6$)

Twenty-six out of 42 autografts of marrow alone showed similar specks of calcification, increasing in quantity from the fourth day onwards.

Histological studies

All implant sites showed evidence of surgical trauma with haemorrhage and surrounding fibrosis. Haemorrhage was readily visible up to about the seventh day in all implants, and the fibrous capsule and fibroblastic reaction was maximal between 4 and 12 days, in all except the undecalcified grafts inserted alone in which this occurred between 8 and 13 days. No differences were noted in the responses to the three different types of wash procedure.

The morphological features were similar, except for the presence of ovoid cells, to those described in guinea pigs by Cummine & Nade (1977).

The staining of osteocytes within lacunae of the implanted bone, the detection of implanted bone, the presence of osteoblasts and newly formed bone and the presence of giant cells require separate description.

a) *Staining of osteocytes* There was a difference in the persistence of histo-

phic nuclear staining of osteocytes in treated allogeneic implanted bone between the decalcified and non-decalcified implants. Such staining could be seen on the day of implantation and the first day afterwards in HCl-decalcified grafts, but was retained until the seventh or eighth day in those not decalcified, but washed before implantation, either combined with marrow or alone.

b) *Detection of implanted bone marrow* Where implants did not contain bone marrow, no features of marrow cells, or fat spaces were seen in combined myelo-osseous grafts, and in marrow autografts alone, the marrow portion of the implant was detected by the cellular distribution pattern and interspersed fat spaces (Figure 2). In marrow autografts the implant site was visible up to the fourteenth day—but decreased in intensity from the eighth day. In combined grafts the marrow component was only easily detected until the seventh or eighth day, except in saline washed non-decalcified grafts where it persisted until the twelfth day.

c) *The presence of osteoblasts and newly formed bone* These two features occurred simultaneously, osteoblasts not



Figure 2 Photomicrograph of undecalcified saline washed allogeneic iliac cancellous bone implant combined with autologous marrow 6 days after insertion. The marrow component is identified by fat spaces (f) and some cellular aggregates adjacent to the implanted bone (ob) within the fibrous capsule (c) (Haematoxylin and eosin $\times 55$)



Figure 3 Photomicrograph of HCl decalcified phosphate washed allogeneic iliac cancellous bone implant combined with autologous marrow 12 days after insertion. The newly formed bone (nb) containing osteocytes and lined by osteoblasts is easily distinguished from the non viable implant (ob) (Haematoxylin and eosin $\times 54$)

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d) *Multinucleated giant cells* These were not seen in marrow autografts, nor around bone which had been decalcified before implantation. In the 252 non-decalcified implants they first appeared about 11 or 7 days after grafting while in the combined grafts (non decalcified) they were first noticed after 8 days with ethanol washed implants. 12 days with saline washed and were seen at various times in phosphate washed implants. The significance of these differences is not clear, however, these cells were always

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DISCUSSION

The stimulation of osteogenesis and the identification of cells which contribute to the synthesis of bone matrix have been studied for over three centuries. The considerable variation in findings reported has been due to the animal species used, the interpretation of histology, the technical differences in laboratories and the acceptance of conclusions from statistically insignificant figures.

In the interpretation of previously described work, one must be careful if one accepts the criterion of nuclear staining of osteocytes as indicating cell viability, for the findings of this study as well as of Yoshiki (1962) and Burwell (personal communication 1970) show that such a stain in non-decalcified stored bone may be retained for up to 7 days, when the cells are by all accepted criteria non-viable.

Previous studies (Nade 1970, Nade & Burwell 1977) have failed to confirm the findings of Urist's group (Urist et al 1968) that HCl decalcified allografts of bone implanted into an intermuscular site evoke the production of newly formed bone, presumably by the process of induction. One variable was the method by which the bone was washed after decalcification. This study shows that the cellular response, in the rabbit, is not influenced by the use of sodium chloride solution, 70 per cent ethanol or an isotonic phosphate buffer. Admittedly, Urist's group have used diaphyseal cortical bone, while this study has used iliac cancellous bone, however, Cummine & Nade (1977) showed that the cellular response around these two types of bone is not different (in the guinea pig).

The findings of earlier reports have been confirmed, and have led to the conclusion that fresh bone marrow auto

grafts are osteogenic (Bruns 1881, Danis 1956, Amsel & Dell 1971) and that marrow cells produce bone in the presence of decalcified allografts of cancellous bone (Burwell 1966, Pike & Boyne 1974). Whether such bone growth is stimulated by the allograft (Sabel et al 1964, Boyne 1970, Buring 1975) or whether it acts purely as a scaffold to retain the marrow autograft *in situ* (Burwell 1966) has not been determined. There is a critical number of cells per unit volume (packing density) below which osteogenesis does not take place (Friedenstein et al 1966, Amsel & Dell 1971). However, the newly formed bone, and adjacent osteoblasts were present on the eighth day after implantation in this study, so that the critical events in the stimulation of osteogenesis occur well before that time has elapsed.

Multinucleated giant cells were yet again (Nade 1970, Nade & Burwell 1977, Cummine & Nade 1977) seen around non-decalcified grafts, suggesting that the cellular morphology around skeletally derived implants is influenced by their physical and/or chemical nature (Young 1966). The significance of such giant cells is unknown, presumably they have a role in demineralization of hard pieces of bone, and by doing so, deplete the cell population surrounding an implant of potentially osteogenic cells.

Although it has been suggested that the influence of skeletally derived tissues is at least partially masked or inhibited when bone is mineralized (Morris 1973, Nade & Burwell 1977) the time at which bone formed was not altered by the failure to decalcify although no attempt was made to assess the quantity of bone that formed.

It has previously been shown (Bloom et al 1941, Tavassoli & Crosby 1968, Nade 1970, 1973) that cells within the bone marrow population are osteogenic. Whether transplanted cells contribute directly by division and differentiation

or whether they degenerate and their breakdown products stimulate bone formation in the surrounding connective tissue has not been clarified and advocates of the former (Dorr et al 1962, Friedenstein et al 1968, Danis 1973) and latter theories (Crosby 1970, Buring 1975) exist. Certainly by light microscopy, one is unable to identify in the first 7 days after implantation those cells which are about to synthesize bone matrix. Cummine & Nade (1977) have described ovoid cells in guinea pigs which appear adjacent to bone implants about the time that osteogenesis commences, but similar cells have not been detected in the rabbit. Perhaps these are the primitive mesenchymal cells, or reticular cells described by Amsel & Dell (1971). Electron microscopy would be a useful tool in determining which cells in the first 7 days after bone marrow transplantation appear to be assuming osteoblast characteristics and bone matrix synthetic activity.

Similar findings have now been described in rabbits of a different strain to those in this study (Nade & Burwell 1977), in the rat (Burwell 1966), the monkey (Boyne 1974), the dog (Newman & Boyne 1971), the guinea pig (Cummine & Nade 1977) and man (Marble et al 1970, Boyne 1974) under various experimental conditions.

The formation of bone by marrow as a fundamental response to injury or insult of that tissue has been proposed (Cummine & Nade 1975) and the ability to control this response by the surgeon should make it possible to stimulate osteogenesis when and where it is required without the need for taking massive bone autografts (Nade 1970, Boyne 1973).

Decalcified allogeneic bone, preferably cancellous for its cell-retaining mesh of trabeculae, could be stored easily in sterile containers by freezing or lyophilisation and used as a relatively non-anti-

genic vehicle for implantation of osteogenic bone marrow—and possibly act as a stimulus to its osteogenic capacity. Despite previous attempts to provide bone-lanks this hypothesis changes emphasis from the cellular to an environmental role for the skeletally derived graft.

Studies of the reconstruction of mandibular defects using such combined myelo-osseous grafts isolated from surrounding cells by a porous membrane (Boyne 1969 Richter & Boyne 1969) have suggested the direct involvement of such marrow cells. Mitchell & Marble (1974) do not believe that the calcified matrix of cancellous bone produces any significant osteogenic effect but acts as a restraining lattice for the marrow cells.

With the realization that living autografted bone marrow cells are osteogenic, clinical trials should be undertaken to assess the potential of this type of boneless bone grafting.

SUMMARY

- 1 This paper reports a radiological and histological study of the fate of hydrochloric acid decalcified allogeneic iliac bone impregnated with autologous bone marrow and grafted to a muscular site in rabbits for up to 14 days.
- 2 After decalcification the bone pieces were washed in either 0.9 per cent sodium chloride solution, 70 per cent ethanol or 0.1 M isotonic phosphate buffer at pH 7.4. The treated pieces of bone were sealed in individual containers and stored by freezing. Non-decalcified bone similarly washed was used as a control in the same animal.
- 3 Bone marrow was obtained by aspiration from the femoral medullary cavity through a drill hole just be-

fore implantation and combined with the treated and stored allogeneic bone.

- 4 Autografts of bone marrow alone produced bone after 7 to 8 days implantation as did combined myelo-osseous grafts.
- 5 In the absence of bone marrow no newly formed bone was seen.
- 6 Non-decalcified implants stimulated the production of multinucleated giant cells about them.
- 7 The type of wash used did not influence the cell pattern seen around the grafts nor the new bone formation.
- 8 The retention of nuclear staining by osteocytes cannot be accepted as evidence of cell viability.
- 9 The results of these and similar experiments using combined grafts of bone and marrow show that bone marrow autografts are osteogenic and this capacity may be controlled by the surgeon by varying the microenvironment in which the marrow cells are placed.
- 10 The critical events in bone formation after marrow injury by transplantation occur less than 8 days after such transplantation.

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REFERENCES

- Amsel S & Dell I S (1971) The radiosensitivity of the bone forming process of heterotopically grafted rat bone marrow *Int J rad Biol* 20 119-127
- Bloom W, Bloom M A & McLean F C (1941) Calcification and ossification Medullary bone changes in reproductive cycle of female pigeons *Anat Rec* 81 443-475
- Boyne P J (1969) Use of marrow grafting in regeneration of the mandibular body *J dent Res Suppl* 48, 96
- Boyne P J (1970) Autogenous cancellous bone and marrow transplants *Clin Orthop* 73 199-209
- Boyne P J (1973) Implants and transplants. Review of recent research in this area of oral surgery *J Amer dent Ass* 87 1074-1080
- Boyne, P J (1974) Use of marrow cancellous bone grafts in maxillary alveolar and palatal clefts *J dent Res* 53 821-824
- Bruns P (1881) Ueber transplantation von knochenmark *Arch Klin Chir* 26 661-668
- During K (1975) On the origin of cells in heterotopic bone formation *Clin Orthop* 110 293-302
- Burwell R G (1964) Studies in the transplantation of bone VII The fresh composite homo graft autograft of cancellous bone an analysis of factors leading to osteogenesis in marrow transplants and in marrow containing grafts *J Bone Jt Surg* 46 B 110-140
- Burwell R G (1966) Studies in the transplantation of bone VIII Treated composite homo graft autografts of cancellous bone An analysis of inductive mechanisms in bone transplantation *J Bone Jt Surg* 48 B 532-566
- Crosby W H (1970) Experience with injured and implanted bone marrow Relation of function to structure In *Haemopoietic cellular proliferation* Ed Stohlman J Jr pp 87-96 Grune and Stratton New York
- Cummine J I & Nade S M L (1975) Avascular necrosis of bone—Is it? 35th Annual Scientific Meeting Australian Orthopaedic Association Sydney
- Cummine J L & Nade S M L (1977) Osteogenesis after bone and bone marrow transplantation I Studies with combined myeloid osseous grafts in the guinea pig *Acta orthop scand* 48 15-24
- Danis A (1956) Etude de l'ossification dans les greffes de moelle osseuse Monograph *Acta med belg* (Brussels)
- Danis A (1973) Le cal de fracture nait de la moelle osseuse directement et indirectement *Acta orthop belg* 39 96-709
- Dorr, A D, Moloney W C, Boschetti A I & Dowd G (1962) Effect of various substrates on growth of autografted marrow in the rat *Kidney Int* 11 377-381
- Iridenstein, A J, Piatetzky Shapiro I I & Petralova K V (1967) Osteogenesis in transplants of bone marrow cells *J Embryol exp Morph* 16 381-390
- Iridenstein A J, Petralova K V, Kurolesova A I & Irolova G P (1968) Heterotopic transplants of bone marrow Analysis of precursor cells for osteogenic and hematopoietic tissues *Transplantation* 6 230-247
- Marble H B, Boyne P J, Luther S R, Koutralos J & Richter H J (1970) Grafts of cancellous bone and marrow for restoration of avulsion defects of the mandible Report of 2 cases *J oral Surg* 28 138-143
- Mitchell W I & Marble H B (1974) Particle marrow graft for restoration of the mandibular symphysis *Oral Surg* 37 196-201
- Morris M I (1973) The effects of homologous bone and matrix with and without marrow on implanted dentin and cementum *J Periodontol* 44 667-674
- Nade S M L (1970) Bone graft surgery re appraised The contribution of the cell to ultimate success *Brit J Surg* 57 752-756
- Nade S M L (1973) *An experimental study into the potential of decalcified bone as a bone bank material Investigations in the induction of post foetal osteogenesis* MD Thesis The University of Sydney
- Nade S M L & Burwell R G (1977) Decalcified bone as a substrate for osteogenesis An appraisal of the inter relation of bone and marrow in combined grafts *J Bone Jt Surg* 59 B 189-196
- Newman N G & Boyne P J (1971) The effect of calcified bone matrix on the osteogenic potential of hematopoietic marrow *Oral Surg* 32 506-512
- Pike R I & Boyne P J (1974) Use of surface decalcified allogeneic bone and autogenous marrow in extensive mandibular defects *Oral Surg* 32 117-182
- Richter H E & Boyne P J (1969) New concepts in facial bone healing and grafting procedures *J oral Surg* 27 557-559
- Sabat J V, Hejna W & Ray R D (1964) Experimental study on bone transplants and implants *J Bone Jt Surg* 46 A 1153
- Tavassoli M & Crosby W H (1968) Transplantation of marrow to extramedullary sites *Science* 161 54-56
- Urist M R, Silverman B I, Buring K, Duhac I & Rosenberg J (1967) The bone induction principle *Clin Orthop* 58 243-283
- Urist M R, Dowell T A, Hay P H & Strates B S (1968) Inductive substrates for bone formation *Clin Orthop* 59 59-96

- Yoshiki S (1962) Experimental study on subcutaneous transplantation of the anorganic bone *Bull Tokyo Dental College* 3 57 65
- Young R W (1966) The control of cell specialization in bone *Clin Orthop* 45 153 156

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REFERENCES

- Amsel S & Dell F S (1971) The radiosensitivity of the bone forming process of heterotopically grafted rat bone marrow *Int J Radiat Biol* 20 119-127
- Bloom W, Bloom M A & McLean F C (1941) Calcification and ossification. Medullary bone changes in reproductive cycle of female pigeons *Anat Rec* 81 443-475
- Boyne P J (1969) Use of marrow grafting in regeneration of the mandibular body *J Dent Res Suppl* 48 96
- Boyne P J (1970) Autogenous cancellous bone and marrow transplants *Clin Orthop* 73 189-209
- Boyne P J (1973) Implants and transplants. Review of recent research in this area of oral surgery *J Amer dent Ass* 87 1074-1080
- Boyne P J (1974) Use of marrow cancellous bone grafts in maxillary alveolar and palatal clefts *J Dent Res* 53 821-824
- Bruns P (1881) Ueber transplantation von knochenmark *Arch Klin Chir* 26 661-668
- Buring K (1975) On the origin of cells in heterotopic bone formation *Clin Orthop* 110 293-302
- Burwell R G (1964) Studies in the transplantation of bone. VII The fresh composite homo graft autograft of cancellous bone: an analysis of factors leading to osteogenesis in marrow transplants and in marrow containing grafts *J Bone Jt Surg* 46 B 110-140
- Burwell R G (1966) Studies in the transplantation of bone. VIII Freated composite homo graft autografts of cancellous bone. An analysis of inductive mechanisms in bone transplantation *J Bone Jt Surg* 48 B 532-566
- Crosby W H (1970) Experience with injured and implanted bone marrow. Relation of function to structure. In: *Haemopoietic cellular proliferation* Ed Stohman F Jr pp 87-96 Grune and Stratton New York
- Cummie J L & Nade S M L (1975) Avascular necrosis of bone—is it? 35th Annual Scientific Meeting Australian Orthopaedic Association Sydney
- Cummie J L & Nade S M L (1977) Osteogenesis after bone and bone marrow transplantation. I Studies with combined myelogenous grafts in the guinea pig *Acta orthop scand* 48 15-24
- Danis A (1956) Etude de l'ossification dans les greffes de moelle osseuse. Monograph *Acta med belg* (Brussels)
- Danis A (1973) Le cal de fracture naît de la moelle osseuse directement et indirectement *Acta orthop belg* 39 696-709
- Dorr A D, Moloney W C, Boschetti A F & Dowd G (1962) Effect of various substrates on growth of autografted marrow in the rat *kidney Int J Invest* 11 377-381
- Friedenstein A J, Piatetzky-Shapiro I I & Petrakova K V (1967) Osteogenesis in transplants of bone marrow cells *J Embryol exp Morph* 13 381-390
- Friedenstein A J, Petrakova K V, Kurolesova A I & Irolova G P (1968) Heterotopic transplants of bone marrow. Analysis of precursor cells for osteogenic and hematopoietic tissues *Transplantation* 11 230-247
- Marble H H, Boyne P J, Luther N R, Houtalos J & Richter H I (1970) Grafts of cancellous bone and marrow for restoration of avulsion defects of the mandible. Report of 2 cases *J Oral Surg* 28 138-143
- Mitchell W I & Marble H H (1974) Partially marrow graft for restoration of the mandibular symphysis *Oral Surg* 37 196-201
- Norris M I (1973) The effects of homologous bone and matrix with and without marrow on implanted dentin and cementum *J Periodontol* 44 667-674
- Nade S M L (1970) Bone graft surgery reappraised. The contribution of the cell to ultimate success *Brit J Surg* 57 762-766
- Nade S M L (1973) An experimental study into the potential of decalcified bone as a bone bank material. Investigations in the induction of post foetal osteogenesis MD Thesis The University of Sydney
- Nade S M L & Burwell R G (1977) Decalcified bone as a substrate for osteogenesis. An appraisal of the interrelation of bone and marrow in combined grafts *J Bone Jt Surg* 59 B 189-196
- Newman H G & Boyne P J (1971) The effect of calcified bone matrix on the osteogenic potential of hematopoietic marrow *Oral Surg* 32 506-512
- Pile R I & Boyne P J (1974) Use of surface decalcified allogeneic bone and autogenous marrow in extensive mandibular defects *Oral Surg* 32 117-189
- Richter H I & Boyne P J (1969) New concepts in facial bone healing and grafting procedures *J Oral Surg* 27 557-559
- Sabot T A, Hejna W & Ray R D (1964) Experimental study on bone transplants and implants *J Bone Jt Surg* 46 A 1153
- Tavassoli M & Crosby W H (1968) Transplantation of marrow to extramedullary sites *Science* 161 54-56
- Urist M R, Silverman B F, Buring K, Duluc F & Rosenfeld J (1967) The bone induction principle *Clin Orthop* 53 243-283
- Urist M R, Dowell T A, Hay P H & Strates B S (1968) Inductive substrates for bone formation *Clin Orthop* 59 59-96

- Yoshida S (1962) Experimental study on subcutaneous transplantation of the anorganic bone *Bull Tokyo Dental College* 3 57 65
- Young R W (1966) The control of cell specialization in bone *Clin Orthop* 45 153 156

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RADIOTHERAPY AND SURGERY IN 50 CASES OF OSTEOSARCOMA TREATED WITHOUT ADJUVANT CHEMOTHERAPY

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A consecutive series of osteosarcoma patients from one hospital is described. In 1962 radiotherapy with delayed surgery according to Cade was replacing surgery alone as the adopted treatment programme. Statistically the results were the same before and after this time with 5 out of 29 and 6 out of 21 patients respectively, surviving 5 years. With radiation alone none out of eight survived. Surgery alone produced 3 out of 14 and radiation with delayed surgery 6 survivors out of 15. As surgery with or without radiotherapy is equally effective in controlling osteosarcoma a prospective randomized trial of the relative merits of chemotherapy and interferon as adjuvant therapy seems highly desirable.

Key words: osteosarcoma, radiotherapy, amputation

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Over the last 5 years the traditional methods of treatment for osteosarcoma including surgery with or without radiotherapy have gradually been replaced by new programmes combining surgery with chemotherapy. Before the introduction of modern programmes of this type the results of earlier regimes have been reviewed.

Evaluation of the results of therapy for osteosarcoma is often made difficult by the fact that consecutive series from single hospitals are generally small. Larger series are always collected from several different clinics and are reliable only when tumour registers are used (Larsson & Lorentzon 1974) but in such series there is always greater variation

in therapy. The material may give valuable information when added to similar series from other clinics and, in the future, assessment of the results in series of this type will also be influenced by the effects of chemotherapy.

In 1962, it was decided at the University Clinic in Lund, to change the principle of therapy for osteosarcoma from surgery alone to radiotherapy with delayed surgery according to Cade (1955). This paper presents the results obtained with the former and the latter programmes both without adjuvant chemotherapy, and discusses the latest trends in the new programmes with chemotherapy.

Table 1 Basic data of all cases of osteosarcoma tabulated in the order of survival time

Case no	Sex	Age	Location	Therapy	Duration of symptoms (months)	Biopsy year	Time in months from biopsy to	
							metastases	death
32	M	12	PH	R	1	1968	at diagnosis	25
23	F	29	PF	S	2	1951	not shown	3
1	F	52	DT	S	7	1962	not shown	3
26	M	70	PFe	H	8	1969	not shown	3
10	M	5	PH	R	1	1951	25	35
3	F	12	DF	R	0.5	1958	1	5
16	M	21	DF	R	6	1959	35	5
28	F	33	DF	S	2	1957	not shown	5
33	M	14	DF	SR	1	1948	3	5
40	M	47	DF	R+6+S	8	1967	at diagnosis	6
44	F	9	DF	SR	3	1962	45	6
9	M	22	PF ₁	R+6+S	3	1949	25	6
2	F	13	PT	RS	2	1956	not shown	7
6	F	8	DF	R	3	1967	2	7
24	M	9	PF	R	2	1953	45	8
20	F	41	Mand	SR	7	1946	45	9
21	F	64	PT	S	2	1957	8	9
18	F	70	Calc	S	6	1952	2	10
39	M	17	DF	RS	1	1946	7	11
8	F	19	PHu	RS	7	1959	4	11
41	F	7	DF	R+6+S	1	1972	4	11
36	F	3	PF	R+6+S	1	1970	3	11.5
19	M	19	DF	S	4	1965	5	11.5
15	M	18	DF	R+6+S	3	1953	55	12
31	F	69	PH	RS	8	1968	not shown	12
38	M	30	DF	RS	7	1961	2	14
49	F	10	DF	R+6+S	7	1962	6	15
34	F	38	DF	S	1	1958	13.5	17
42	M	7	PH	R	1	1952	14	17.5
17	M	21	DF	R+6+S	12	1965	12	18
43	M	11	PH	R+6+S	4	1968	4	19.5
30	M	26	DF	S	10	1943	13.5	22.5
7	F	33	DR	S	5	1957	6	22
31	M	44	PH	R+6+S	6	1969	7	27.5
4	M	17	DF	S	2	1960	26	41
21	F	32	PT	SR	7	1945	not shown	53
48	M	19	PT	R	5	1966	35	72
13	F	35	PT	S	16	1947	98	102
50	F	22	PH	SR	7	1952	132	156
12	M	10	PT	R+6+S	9	1972	None	Alive (5 years)
11	F	33	Scap	S	3	1970	None	Alive (7 years)
45	M	22	DF	RS	2	1969	None	Alive (8 years)
30	F	41	PT	R+6+S	4	1967	4	Alive (10 years)
5	M	11	DF	R+6+S	11	1965	None	Alive (12 years)
47	M	20	PT	R+6+S	4	1963	16	Alive (14 years)
37	F	11	DF	R+6+S	6	1959	None	Alive (18 years)
23	M	16	PT	S	2	1958	47	Alive (19 years)
14	M	16	DF	R+6+S	3	1953	None	Alive (24 years)
19	M	13	DF	S	3	1953	None	Alive (24 years)
38	M	5	DF	RS	7	1949	None	Alive (28 years)

D = distal F = femur H = humerus P = proximal R = radiotherapy only RS = radiotherapy followed immediately by surgery R+6+S = radiotherapy followed by surgery delayed 3 6 months
S = surgery only T = tibia

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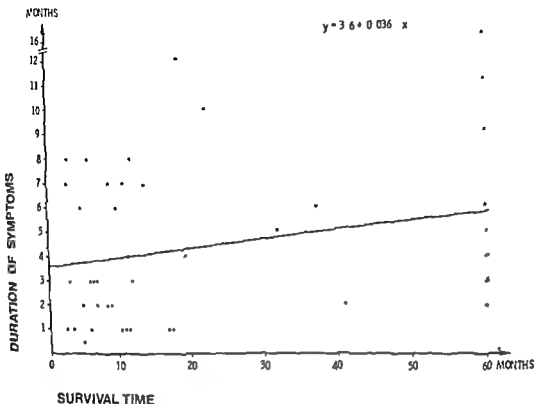


Figure 2 Survival time versus duration of symptoms

duration of symptoms in months before biopsy and the time interval in months before evidence of metastases and before death ensued. There is some correlation between age and duration of symptoms (Figure 1). Survival time versus duration of symptoms is shown in Figure 2. No case with symptoms for 2 months or less were among the survivors but in general the correlation in this material is weak. Before 1962 5 cases out of 29 survived 5 years. From 1962 6 out of 21 survived 5 years. Before 1962 12 out of 29 patients were treated with surgery alone. From 1962 2 out of 21 were treated with surgery alone. The general 5-year survival was 17 per cent before 1962 and 29 per cent since 1962 but the difference is not statistically significant according to Fischer's test ($P = 0.054$ for the combined material). In the total

material of 50, 8 patients treated with radiation alone produced no survivors. Surgery alone produced 3 out of 14 and delayed surgery after radiation six 5-year survivors out of 15 (Tables 1, 2, 3).

Table 2 Survey of planned therapy and disease free survival

Therapy	No	5 year survival
Amputation only	14	3
Amputation + secondary radiotherapy	5	0
Radiotherapy for delayed amputation	15	6
Radiotherapy + immediate amputation	8	2
Radiotherapy only due to metastases	8	0
Total	50	11

MATERIAL

During the period 1945 through 1972, 74 patients with a diagnosis of osteosarcoma were registered at the University Hospital in Lund, Department of Orthopaedic Surgery or Radiotherapy. After reviewing our records and histological preparations, 50 were accepted as osteosarcoma according to the WHO classification. Twenty-four cases were rejected by the histopathologist as chondrosarcoma (8), fibrosarcoma (4), undifferentiated sarcoma (3), giant cell tumour (2), chondromyxosarcoma (2), osteoblastoma (1), fracture (1), Ewing sarcoma (1). In two patients the histological preparations were unacceptable for a diagnosis and the cases were rejected. In three, cytological needle biopsy preparations alone were accepted at the review.

The distribution of age was typical and there were 27 males and 23 females (ratio 1.3:1). If only patients below 25 are considered the ratio is 2.4:1. Table 1 presents the basic data of all 50 patients with osteosarcoma.

METHODS

Up until 1962 the principle of therapy was amputation when surgically possible. For sarcoma in the distal femur transmedullary amputation was used. For sarcomas in the diaphyseal region or more proximally disarticulation was performed. Radiotherapy was used only for cases where surgery was impossible or where it had been tried but proven insufficient at pathology.

From 1962, biopsy was followed by radiotherapy according to Cade (1955) but using high voltage equipment. Doses of 500–7500 rad were given and amputation was carried out 4–6 months later. In cases where fracture or continuation of tumour growth occurred in spite of radiotherapy, amputation was performed earlier.

RESULTS

Table 1 describes the cases in order of survival time. Sex, age and location of tumour are shown as well as therapy.

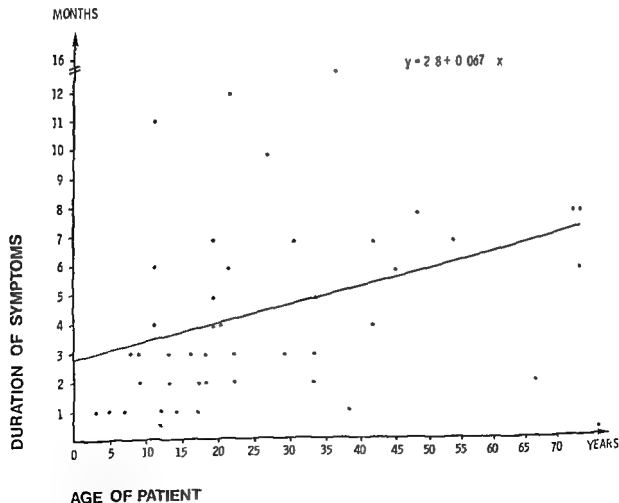


Figure 1 Age versus duration of symptoms

limb and replacing the structure with a custom made prosthesis Jaffe & Watts (1976) conclude that a transmedullary amputation through the involved bone rather than removal of the entire bone should now be safer than before (Toss et al 1966)

The rarity of osteosarcoma and the delicacy of cytostatic adjuvant programmes now more than ever make centralized treatment with coordinated programmes a necessity. As soon as the results of adjuvant interferon are finally analyzed it should be possible to begin a Scandinavian programme comparing interferon with chemotherapy. Surgery alone or preoperative radiotherapy with delayed surgery both have proven in sufficient but statistically comparable. From now on adjuvant programmes are running prospectively to make contemporary controls possible.

REFERENCES

- Cade S (1955) Osteogenic sarcoma. A study based on 133 patients. *J roy Coll Surg (Edn b)* 1 79-111
- Campanacci M & Cervellati C (1975) Osteosarcoma. (A review of 315 cases). *Ital J Orthop Traumatol* 1 5-22
- Cederlof S, Hjertqvist T & Salen F (1960) A follow up study of osteogenic sarcoma. *Acta orthop scand* 30 107-114
- Cortez F P, Holland J F, Wang J J, Sinks L F, Blom J, Segal H, Bank A & Glidewell M (1974) Amputation and Adriamycin in primary osteosarcoma. *New Engl J Med* 291 995-1001
- Dahlöf D C & Lorenz M B (1967) Osteogenic sarcoma. A study of six hundred cases. *J Bone Jt Surg* 49 A 101-110
- Foss H P., Brennhovd I O., Vesselt O T., Ifskind I & Liverud K (1966) Invasion of tumour cells into the bloodstream caused by palpation or biopsy of the tumour. *Surgery* 59 691-695
- Jaffe N & Watts H G (1976) Multidrug chemotherapy in primary treatment of osteosarcoma. *J Bone Jt Surg* 58 A 634-635
- Larsson S E & Lorenz M B (1974) The incidence of malignant primary bone tumours in relation to age, sex and site diagnosed in Sweden 1958 to 1968. *J Bone Jt Surg* 56 B 534-540
- Lindblom A, Söderberg C & Spjut J (1961) Osteosarcoma. A review of 96 cases. *Acta radiol (Stockh)* 56 1-19
- Marove R (1975) New trends in the treatment of osteogenic sarcoma. *Orthop Digest* 3 11-14
- Heff J R & Finckh W F (1975) Adoptive immunotherapy in primary osteosarcoma. *J Bone Jt Surg* 57 A 145-148
- Nilsson L., Strandberg H & Jacobsson P (1975) Osteosarcomabehandling med interferon och amputation eller lokal resektion. *Acta Soc Med Suecane* 84 376-378
- Poppe F, Liverud K & Efskind J (1968) Osteosarcoma. *Acta chir scand* 134 549-556
- Rosen G, Swanson R, S. Huan C, Tan C, Wu S J, Beattie F J & Murphy M L (1974) High dose methotrexate with citrovorum factor rescue and adriamycin in childhood osteogenic sarcoma. *Cancer* 33 1151-1163
- Sweetnam R, Howledge I & Jeddin H (1971) Bone sarcoma. Treatment by irradiation amputation or a combination of the two. *Brit med J* 2 363-367
- Sutloff W W, Sullivan M P & Fernbach D J (1974) Adjuvant chemotherapy in primary treatment in osteogenic sarcoma. *Proc Amer Ass Cancer Res* 15 20
- Trifaud A & Meaux B (1962) Traitement des sarcomes ostéogéniques. *J Chir (Paris)* 104 180-191

Table 3 High voltage radiation before delayed surgery, primary plan and final outcome

Therapy	No	5-year survival
Amputation after 6 months	8	6
Amputation before time due to complications	2	0
Amputation not carried out due to metastases	5	0
Total	15	6

DISCUSSION

This consecutive and unselected series shows a 5-year cure rate and a 5-year survival rate of 18 and 26 per cent, respectively. Four patients had pulmonary metastases resected, two were disease-free 5 years later. When the material is divided according to therapy, the group with radiation and delayed surgery has a survival rate and a cure rate which is greater than those with surgery alone but the differences are not statistically significant.

In 1962 the Cade principle was adopted. When the results after this time are compared with those from the earlier period the survival rate is a bit better but again the difference is statistically not significant. Many materials support this conclusion (Cederlof et al 1960, Dahlin & Coventry 1967, Lindblom et al 1961, Pope et al 1968). Sweetman et al (1971) recorded 14 out of 61 surviving amputation alone and 22 out of 80 surviving radiotherapy with delayed amputation. In France, Trifaud & Merry (1972) made a broad-based review of the literature studying this question and recorded a 21 per cent 5-year cure rate with amputation alone in 903 cases and a 23 per cent rate with delayed surgery after radiotherapy in a series of 501 cases studied. The material presented in this paper agrees with this. It should therefore be remembered that in cases where immediate surgery for

one reason or another is not feasible, radiotherapy with the surgery postponed for 4 to 6 months does not adversely influence the results. This type of programme should not be used in cases where the tumour has already made the function of the limb inferior to that of a prosthesis. When the function is good and the pain is controlled by the radiotherapy the possibility of delaying surgery must be kept in mind for special cases. Campannacci & Cervellati (1973) from Italy reviewing 345 cases came to the same conclusion.

Since the first trials with chemotherapy (Phenylalanine mustard in Huston, Texas, in 1963) Adriamycin alone or in combination with other drugs has produced encouraging early results. Pritchard (1976, personal communication) at the Mayo Clinic believes that during the last 5 years the general prognosis of osteosarcoma may be better than before thereby making historical controls for evaluating the effects of chemotherapy misleading. The 2-year survival rates seem to rise from around 30 per cent without chemotherapy to between 50 and 75 per cent with chemotherapy (Cortes et al 1972, Jaffe & Watts 1976, Rosen et al 1974, Sutow et al 1974).

Other types of adjuvant therapy for osteosarcoma which have been tried with hopeful early results are adoptive immunotherapy (Neff & Enneking 1973) and interferon (Nilsson et al 1975). Interferon as an effective adjuvant to surgery may support the theory of a viral aetiology.

Although it is not proven that these adjuvant programmes are producing better results in the long run, the early figures have given a new interest in reducing the magnitude of mutilating surgery for these patients. Marceve (1975, 1977, personal communication) as well as Sneath (1976, personal communication) are concentrating on extirpation of the bone involved with preservation of the

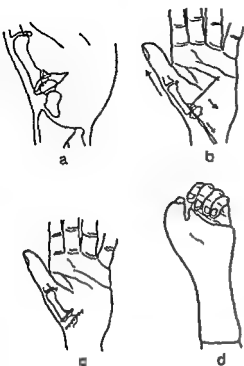


Figure 2 Internal fixation ad modum Gedda & Moberg (1953)

treatment and presenting a great many cases. Subsequent progress in the field of internal fixation has made it possible to develop the method of treatment described by Moberg (1952) (Figure 2).

Gedda pointed out that the prognosis for Bennett's fracture depends to a great extent on the choice of therapy. If exact or almost exact reduction can be achieved, the results are very good.

The internal fixation of Bennett's fracture can be performed by means of a screw (Ruedi et al 1971) or a Kirschner wire (Moberg 1952), depending on the size of the tuberculum fragment. The purpose of screw fixation is to achieve a rigid internal fixation. Difficulties arise, however, in maintaining the reduction of the fracture during the insertion of the implant and in securing an ideal position for the implant. With the instruments described below, the operation is simplified and there is less need for assistance

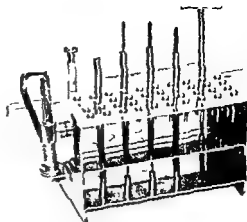


Figure 3 Instrumentarium

MATERIAL AND METHODS

The set of instruments (Figure 3)

The instrumentarium consists of the following:

- 1 A guide and fixation instrument, with a guide hole that is some tenths of a mm wider than the head of the osteosynthesis screw (Figure 4).
- 2 One 2.7 mm and one 2.0 mm wide drill fitted to batons that are slightly smaller than the hole in the guide instrument (Figure 5 a + b).
- 3 A threaded tap fitted to a baton of the same thickness as those for the drills (Figure 5 c).
- 4 A screw driver of the Phillips type for the osteosynthesis screw (Figure 5 d).
- 5 A guide for the Kirschner wire, resembling a thick walled tube. Its external diameter is the same as that of the hole in the guide and fixation instrument and its internal diameter is some tenths of a mm larger than the Kirschner wire (Figure 5 e).

In the case of big fragments, the internal

rotation and damage to the fragment than a cancellous screw. In cases of small fragments the internal fixation is performed by means of a 2 mm Kirschner wire. Whether a screw or a wire is used it must run perpendicular to the fracture surface.

COMPRESSION FIXATION OF BENNETT'S FRACTURE

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A procedure that ensures exact reduction and internal fixation of Bennett's fracture is presented. In cases with a large tubercular fragment, the internal fixation is performed with a lag screw technique. If the fragment is small, a Kirschner wire is used as an implant. A special set of instruments that keeps the reduced fragment in position and guides the implant during the internal fixation process is also described.

Key words: Bennett's fracture, small fragment fracture, metacarpal fracture, thumb injury, internal fixation, internal fixation of small fragments, lag-screw fixation.

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Ever since 1882, when the Irish surgeon E. H. Bennett described a fracture of the palmar tuberculum of the first metacarpal, causing subluxation in the first metacarpal joint (Figure 1), this injury has attracted great interest, in spite of the fact that it is relatively uncommon. In a large number of fracture injuries, Bennett's fracture accounts for only 0.4 per cent (Gedda 1954). There are two main reasons for this interest:

1. A neglected or incorrectly treated Bennett's fracture will cause a posttraumatic osteoarthritis in the first metacarpal joint. The loss of stability in the joint considerably reduces the force of the thumb and with it the gripping ability of the hand. The injury tends to affect the hand of preference in people in their most active age and can considerably impair their capacity for work.

2. The fracture has earned the reputation of being easy to reduce but difficult to keep in position.

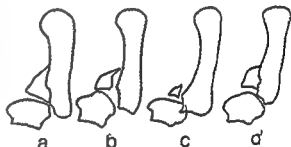


Figure 1. Bennett's fracture (classical forms (a and b) with small fragment (c) and impact fracture (d)).

A great variety of treatments, open as well as closed, have been described and recommended (Moberg 1952, Ivarste & Cedard 1959, Emerle 1960, Pollen 1968). The underlying principles are difficult to evaluate because none of the published series has exceeded 15 cases, with the exception of the monograph by Gedda (1954). This work on Bennett's fracture is the most extensive and important, discussing comprehensively the history, mechanics, pathophysiology, diagnosis and

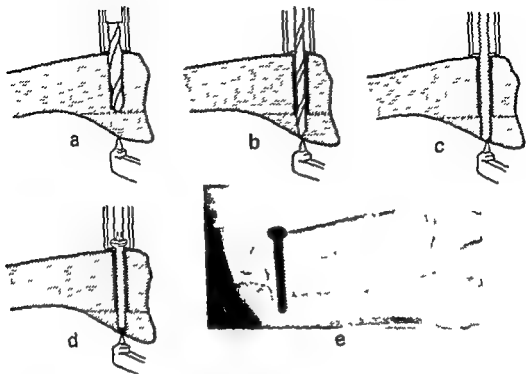


Figure 6 Performance of internal fixation a) drilling through main fragment b) drilling through palmar fragment c) tapping d) inserting screw e) screw applied

indicating the length of the screw required (Figure 4). The screw temporarily fixed to the screw-driver with albumin for example is inserted through the main instrument and screwed into the bone tunnel (Figure 6d). This results in rigid fixation of the fracture and compression between its surfaces. The muscles are sutured and the incision closed.

If the palmar fragment is too small to be screwed internal fixation with compression must be abandoned. The fragment is instead fastened with a Kirschner wire as described by Moberg (1932). This can be successfully accomplished with the instruments described above. When the fracture has been temporarily reduced the tubular guide (Figure 5a) for the Kirschner wire is inserted into the tunnel in the main instrument. The wire is fastened into a hand surgeon's drill and placed in the tubular guide so that it can be drilled through the cortex of the main fragment and out through the cortex of the palmar fragment (Figure 7a). The wire is passed out of the palmar fragment close to the tip of the main instrument. The main instrument is then removed and the wire cut off.

The joint is immobilized in a plaster bandage

extending from the interphalangeal joint of the thumb engaging the entire middle hand and up onto the forearm. The operated hand is kept in an elevated position.

With internal fixation by means of a screw, the plaster is removed after 3 weeks and the screw after 2 months. With Kirschner wire fixation the plaster must be retained for at least 4 weeks and the wire extracted after a further 2 months. As soon as the plaster has been removed the patient should start to exercise the hand and fingers.

The operation need not be performed in the acute stage but preferably within 1 week after the accident. This allows time for preoperative preparation of the skin and for the traumatic oedema to decrease. The internal fixation material should be removed 4 months after operation—a procedure for the outpatient department.

Patients

During a 5 year period the instruments described have been used in 11 patients, all men between 20 and 54 years of age. All the injuries had involved the hand of preference and caused

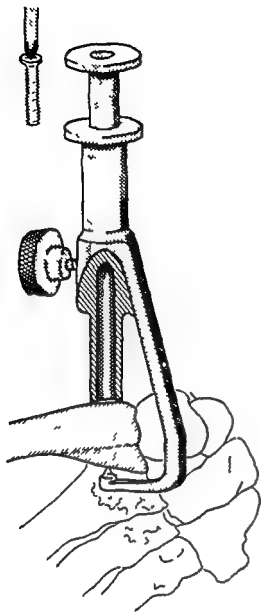


Figure 4 Guide and fixation instrument

Procedure

The fracture is exposed as described by Möberg (1951) and Gedda & Möberg (1953) (Figure 2a). The operation is performed under general or regional anaesthesia. An arched incision (Figure 2) approximately 3 cm long is made over the base of the thenar muscles at right angles to the line of the thumb on the volar side of the tendon to adductor pollicis longus. The thenar muscles must be partially dissected from the aponeurosis. The joint is opened and the fracture haematoma and small crush fragments are removed. Traction is applied along the axis of the thumb at about 60° to the axis of the forearm. Thus the subluxation and the fracture are reduced under visual control. In order to maintain traction a silk netting for

finger traction (Silk finger grip Zimmer C B) may be used. This netting can be fastened to the operation table so that the reduction is maintained while the osteosynthesis is carried out. The sharp tip of the main instrument is placed on the palmar fragment and the cylinder is pressed down against the main fragment (Figure 4). In this way, the fracture is temporarily fixed while fully visible and a check can be made that continuity of the joint surface is restored. A lock screw in the main instrument is used to keep the cylinder in place.

The 27 mm drill is fitted to a hand surgery drill and inserted into the hole in the cylinder. A hole is drilled through the cortex of the main fragment (Figure 6a). After this a hole is drilled in the same way through the cancellous bone and the cortex of the palmar fragment with the 2 mm drill (Figure 6b). The tip of this drill passes close to the tip of the main fragment. The tap is used to produce a thread in the drilled tunnel (Figure 6c). The two plates on the main instrument are now as far apart as the length of the drilled tunnel in

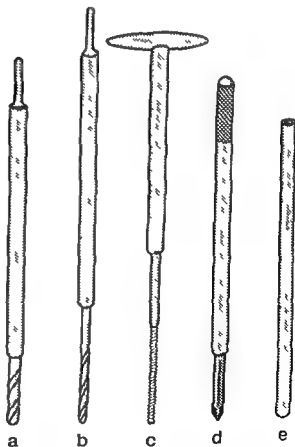


Figure 5 Auxiliary instruments for internal fixation a) 97 mm drill b) 20 mm drill c) tap d) screw driver Phillips type e) guide for Kirschner wire

by means of the lag screw technique or with the aid of a Kirschner wire, and the method described reduces the need for assistance

REFERENCES

Bennett, F H (1882) Fractures of the metacarpal bones *Brit med J* 7A 72-73
 Gedda H H (1934) Studies on Bennett's fracture *Acta chir scand* Supp 193
 Gedda H O & Moberg F (1953) Open reduction and osteosynthesis of the so-called Bennett's fracture in the carpo-metacarpal joint of the thumb *Acta orthop scand* 22 249-256

Lemerle M P (1960) Les fractures de la base du premier métacarpien *Chir 15* 4-19
 Lataste J & Lédard C. (1939) Les fractures de la base du 1^{er} métacarpien *Presse méd* 67 610-614
 Moberg F (1952) Operativ behandling av Bennefrakturen *Nord Med* 47 751-752
 Müller M E., Allgwer M & Willenegger H (1965) *Technique of internal fixation* Springer Verlag Berlin Heidelberg New York
 Pollen A H (1968) The conservative treatment of Bennett's fracture subluxation of the thumb metacarpal *J Bone Jt Surg* 50B 91-101
 Ruedi T P, Burri C. & Pfeiffer H M (1971) Stable internal fixation of fractures of the hand *J Trauma* 11 381-389

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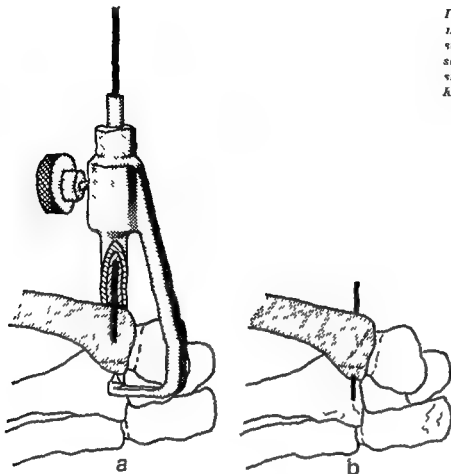


Figure 7 Kirschner wire guide in main guide and fixation instrument a) Kirschner wire inserted b) internal fixation of a small palmar fragment with a Kirschner wire

fractures of the palmar tuberculum of the first metacarpal bone with concomitant subluxation of the thumb

Nine of the cases were treated by means of the lag screw technique and two with Kirschner wires as internal fixation material. All the patients presented good primary results and 2 years after the operation there was no residual incapacity of the thumb in 10 patients. In one patient who was notoriously rosy, the internal screw fixation and the good reduction achieved was eliminated in a new fight some days after the operation.

None of the cases have been followed for more than 2 years postoperatively. The implants were removed 4 months after surgery in all cases except the one where the internal fixation was ruined.

DISCUSSION

All reports of Bennett's fracture point out the necessity of reducing both the subluxation in the metacarpal joint and the fracture. It is generally considered

and postulated that exact reduction and reconstruction of the joint surface in intra-articular fractures prevents post-fracture osteoarthritis.

It is impossible to determine during the operative procedure whether the reduction achieved is exact without opening the joint capsule and evacuating the haematoma (Gedda 1954). Furthermore, the small fragments of cancellous bone must be removed to enable exact reduction and performance of a rigid internal fixation.

The treatment of Bennett's fracture with internal fixation, as described above, decreases the risk of postfracture osteoarthritis by increasing the chance of achieving and maintaining exact reduction. The method permits reduction under visual control and the reduction is maintained during the fixation procedure. The fixation is accomplished either

by means of the lag screw technique or with the aid of a Hirschner wire and the method described reduces the need for assistance

REFERENCES

- Bennett, J. H. (1882) Fractures of the metacarpal bones *Brit med J* **VB** 79 75
- Gedda, H. O. (1934) Studies on Bennett's fracture *Acta chir scand* Supp. 193
- Gedda, H. O. & Moberg, E. (1933) Open reduction and osteosynthesis of the so called Bennett's fracture in the carpo metacarpal joint of the thumb *Acta orthop scand* **2** 249-256
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- Latapie, J. & Celard, C. (1959) Les fractures de la base du 1^{er} metacarpien *Presse med* **67** 610-614
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THE CARPUS IN CONGENITAL ANOMALIES OF THE HAND

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Hukusima, Osaka, Japan

Congenital anomalies of the carpus associated with congenital hand and upper limb anomalies were investigated from the point of view of the development of the hand. Defects of the carpus were categorized as follows: 1) Radial ray defect: loss of the scaphoid, trapezium and trapezoid; 2) Central ray defect: loss of the capitate and loss of a part of the trapezium and hamate; 3) Ulnar ray defect: loss of the triquetrum, pisiformis and hamate. Deficiencies of the carpus and more distal parts of the hand proved to be secondary to defects of the forearm bones in both the radial and ulnar ray. On the other hand, deficiency of the carpus was secondary to defects of the phalanx and metacarpal of the middle finger in the central ray. Thus from the standpoint of the development of the carpus, bipolar development of the bones of the hand originates proximally in both the radial and ulnar rays and distally in the central ray.

Key words: carpal bones, congenital anomaly, radial, central, ulnar rays

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Congenital anomalies of the carpal bones are rare. Isolated carpal anomalies such as fusion, absence, separation and accessory bone have however been documented (Hammond 1947, Rushforth 1949, Waugh & Sullivan 1950, Lockshott 1966, Roche 1967, Szaboky 1969, Gurn et al 1971, Srivastava & Koehhar 1972). On the other hand, carpal bone anomalies are frequently observed in association with other congenital hand and limb anomalies, thus indicating the relationship of carpal bone development to the development of the whole limb (O Rahilly 1953, Poznanski & Holt 1971, Kelikian 1974). However, the development of the carpus, in relation to the development of the whole limb or the hand, has not been

clearly documented. In what way deficiency of the carpus is related to limb deficiency, or correlates with finger deficiency has not been elucidated.

Limb anomalies have been classified in various ways. Frantz & O Rahilly (1961) divided limb defects into two groups, viz, terminal and intercalary defects. Entin et al (1966) and Swanson (1966) outlined the original classification based on embryological considerations in the committee report to the American Society for Surgery of the Hand. Kay and associates (Kay et al 1973), a working group of the International Society for Prosthetics and Orthotics proposed an international terminology for the classification of congenital limb deficiencies,

according to the longitudinal and transverse deficiency based upon embryological considerations

In the present paper an attempt will be made to classify anomalies of the carpus in relation to the precursor defect of each anomaly in order to establish the developmental relationship between the carpus the whole limb and the hand

PATIENTS

Among the Japanese patients with congenital anomalies of the hand who attended the Hand Clinic at Osaka University Hospital during the past 10 years 19 cases of radial ray defects 8 cases of ulnar ray defects and 30 cases of cleft hands were investigated (Table 1). Of these cases 19 were sufficiently developed to permit X-ray evaluation

Table 1 Fifty seven cases with congenital anomalies of the hand

	Total cases	Nature cases
Radial ray defect	19	12
Cleft hand	30	5
Ulnar ray defect	8	2

FINDINGS

Radial ray defect

Riordan (1935) divided congenital absence of the radius into two main groups, i.e. total absence and partial absence and described the associated carpal bone anomalies. Heikel (1959) also reported three types of radial ray defects combined with carpal bone anomalies. According to the extent of the longitudinal defect of the radius we divided the radial ray defect into four groups

- 1) total radius defect (very severe)
- 2) partial radius defect (severe)
- 3) hypoplastic radius (mild)
- 4) normal radius (minimal)

Carpal bone anomalies in each group

were investigated. Ten cases were bilateral and nine unilateral. There were eleven males and eight females. Carpal anomalies occur in various ways depending on the grade of radial ray defect. The most severe type shows total radius defect with or without absence of the thumb and index finger (Figure 1). In this type, the scaphoid, trapezium and trapezoid bones are generally absent, but the other carpal bones are always intact. Occasionally, the central carpal bones are fused.

The next group shows a partial radius defect associated with a total defect of the scaphoid and trapezium (Figure 2). In these cases floating thumb, hypoplastic thumb or other severe anomalies of the thumb with a defect of the first metacarpal are usually present.

The third group presents a hypoplastic trapezium and/or defect of the first metacarpal (Figure 3). Eaves & Campiche (1922) reported a similar case.

In the fourth group there is a normal radius with a hypoplastic thumb. This anomaly is considered to be the most benign and presents only a hypoplasia of the scaphoid and trapezium (Figure 4). Hanley & Conlon (1957) described the benign form of the radial defect. Thus, the carpal bone anomaly appearing in each grade of radial ray defect ranges from very severe to minimal. It varies in extent and severity depending upon the radial ray defect (Figure 5). The development of the radial carpal bones, which include the trapezium, trapezoid and scaphoid is apparently closely related to the development of the radius. The development of the thumb and first metacarpal appears to be related to the development of more the distal parts.

Ulnar ray defect

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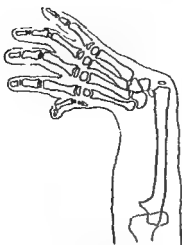


Figure 1. Roentgenogram of the right hand of an 8 year-old girl showing total radius defect floating thumb and a most severe anomaly of the carpal bones, i.e., defect of the trapezium and scaphoid and fusion between the capitate and trapezoid

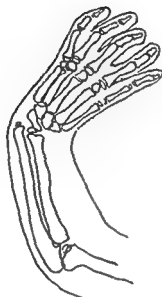


Figure 2. Nine-year-old girl. Note the partial defect of the radius five fingered hand and severe anomaly of the carpal bones, i.e., total defect of the scaphoid and trapezium and fusion between the lunate and triquetrum



Figure 3. Ten-year old girl. Note the hypoplastic radius partial defect of the first metacarpal, defect of both the scaphoid and trapezoid, and hypoplastic trapezium

Figure 4 Twenty three year old female complained of hypoplasia of the left thumb and thenar muscles. Note the hypoplasia of the scaphoid and trapezium also.

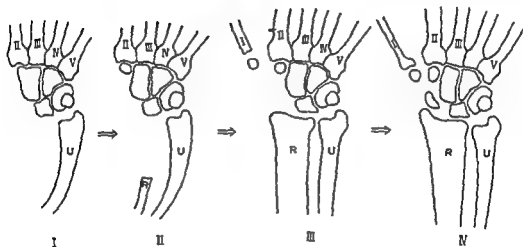
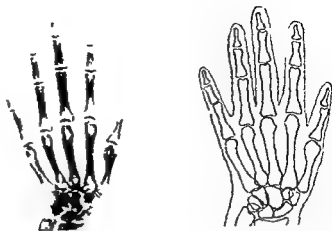


Figure 5 Illustration of the grades of severity of the radial ray defect. Abnormality of the radial carpal bones is also classified into four grades according to the severity of the defect of the radius itself.

bone anomaly however was not included in their reports. In the present work we studied eight cases in which carpal bone anomalies were combined with ulnar ray defects. The ulnar ray defect is classified according to the longitudinal defect of the ulna but is a less common anomaly than the radial ray defect. This defect involves the ulna, carpal bones and the two ulnar fingers and ranges from total ulnar defect to mere hypoplasia of the little finger alone. The triquetrum, pisiformis and hamate are absent, hypo-

plastic or fused depending on the grade of ulna defect. In our series, eight cases were registered but only two cases were mature enough to be classified as partial defect of the fifth metacarpal associated with carpal anomalies. In one of these two cases there was fusion of capitate, hamate and hypoplasia of triquetrum and pisiformis (Figure 6). The severity of this case resembles that seen in the third group of patients with a radial ray



Figure 6 Seventeen year old girl with hypoplasia of the ulna partial defect of the fifth metacarpal and carpal bone anomalies



Figure 7 Eighteen year old girl with anomalies similar to the carpal bone anomalies of the case in Figure 6 Ossal syndactyly of middle and ring fingers is also evident



Figure 8 Eleven year old girl with defects of the second and third metacarpals and the capitate



defect In the second case, a hypoplastic fifth metacarpal with a normal ulna was associated with fusion of the capitate

hamate and hypoplasia of triquetrum and pisiformis (Figure 7) Because osseous syndactyly of the middle and ring fingers

Figure 9 Roentgenogram of a 10 year old boy with total defect of the third metacarpal and a fairly normal capitate

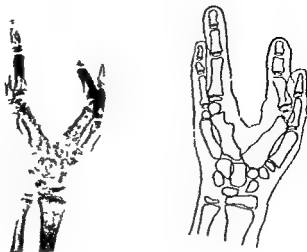


Figure 10 Fifteen year old boy with a partial defect of the third metacarpal and normal carpal bone



was also present this does not appear to be a typical case of ulnar ray defect. Thus the development of the ulnar carpal bones in the ulnar defect is much the same as that in the radial ray defect.

Central ray defect cleft hand

Thirty cases in which carpal bone anomalies were combined with a central ray defect were studied.

Left hand includes various types of anomalies and classification has been made by many authors. Barsky (1961) divided these into the typical and atypical types. The atypical types included other anomalies such as symbrachydactyly,

congenital amputation or microdactyly. In the present study, 30 cases were considered typical cleft hand. Eight hands were sufficiently mature for evaluation and were classified according to the extent and grade of the central ray defect. Various degrees of carpal bone defect were also noted. The defects were graded and divided into three groups. The most severe group shows a total defect of the metacarpal and possibly neighbouring metacarpals (Figure 8). The carpal anomaly in this case includes total defect of the capitate and partial defect of the hamate and trapezium. By contrast the other carpal bones are fairly intact.

In the next group, only a third of the



Figure 6 Seventeen-year-old girl with hypoplasia of the ulna, partial defect of the fifth metacarpal and carpal bone anomalies.



Figure 7. Eighteen-year-old girl with anomalies similar to the carpal bone anomalies of the case in Figure 6. Osseal syndactyly of middle and ring fingers is also evident



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REFERENCES

- Barsky A J (1964) Cleft hand classification: incidence and report of nineteen cases *J Bone Jt Surg* 46 A 1707-1720
- Lockshott W H (1969) Pisiform hamate fusion *J Bone Jt Surg* 51 A 778-780
- Laves J & Campiche P (1922) Note on a malformation of the carpus *J Bone Jt Surg* 4 78-80
- Entin M A, Barsky A L & Swanson A (1966) Committee report to American Society for Surgery of the Hand
- Frantz C H & O'Rahilly R (1961) Congenital skeletal limb deficiencies *J Bone Jt Surg* 43 A 1202-1224
- Garc S M, Frisancho A R, Poznanski A K, Schweitzer J & McCann M B (1971) Analysis of triquetralunate fusion *Amer phys Anthropol* 34 431-433
- Hammond G (1947) Unilateral congenital synostosis of lunate and triangular bones *Surgery* 22 566-567
- Hanley T & Conlon P C (1957) Congenital deformity of the carpus associated with maldevelopment of certain thenar muscles *J Bone Jt Surg* 39 B 458-462
- Heikel H F (1959) Aplasia and hypoplasia of the radius *Acta orthop scand* Suppl 39
- Kato K (1924) Congenital absence of the radius *J Bone Jt Surg* 6 589-626
- Kay M W et al (1973) A proposed international terminology for the classification of congenital limb deficiencies. The recommendations of a Working Group of the International Society for Prosthetics and Orthotics
- Kehlikian H (1974) *Congenital deformities of the hand and forearm* W H Saunders, Philadelphia
- Ogden J A, Wason H K & Bohne W (1976) Ulnar dysmelia *J Bone Jt Surg* 58 A 467-473
- O'Rahilly R (1953) A survey of carpal and tarsal anomalies *J Bone Jt Surg* 35 A 626-639
- O'Rahilly R (1961) Morphological patterns in limb deficiencies and duplications *Amer J Anat* 89 135-193
- Poznanski A K & Holt J I (1971) The carpus in congenital malformation syndrome *Amer J Roentgenol* 112 443-459
- Riordan D C (1955) Congenital absence of the radius *J Bone Jt Surg* 37 A 1129-1140
- Roche A F (1967) Absence of lunate *Amer J Roentgenol* 100 523-525
- Rushforth A F (1949) Congenital abnormalities of trapezium and first metacarpal bone *J Bone Jt Surg* 31 543-547
- Srivastava K P & Kochhar V L (1972) Congenital absence of the carpal scaphoid *J Bone Jt Surg* 54 A 1782
- Straub L R (1965) Congenital absence of ulna *Amer J Surg* 109 300-305
- Swanson A B (1966) Classification of limb malformations on the basis of embryological failures *Inter Clin Infor Bull* 6 (3) 1-15
- Szabo G T, Muller J, Melnick J & Tamburro R (1969) Anomalous fusion between the lunate and triquetrum *J Bone Jt Surg* 51 A 1001-1004
- Waugh R L & Sullivan R F (1950) Anomalies of the carpus *J Bone Jt Surg* 32 A 682-686

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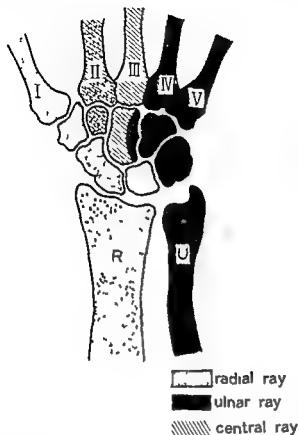


Figure 11 The three rays to which each element belongs

metacarpal and the middle finger are absent with the other finger rays intact (Figure 9). Partial defect or hypoplasia of the capitate is sometimes observed but in other cases it is normal. In the most benign group, a partial defect of the third metacarpal and defect of the middle finger are observed. The carpal bones are always normal in this type (Figure 10).

DISCUSSION AND CONCLUSION

In 1924 Kato postulated that the upper extremity consisted of a main stem and four accessory rays. Since his report the terms "radial ray" and "ulnar ray" have been used and applied for purposes of morphological description of limb deficiency, such as radial hemimelia or ulnar hemimelia (O'Rahilly 1951). The present concept is based on limb development

with the forearm and hand consisting of three rays, i.e., radial, ulnar and central. However, exactly where each carpal bone should be placed appropriately with reference to these rays has not been defined nor has the precursor defect of each carpal bone deficiency.

Based on the clinicoradiological study of 57 hand anomalies the following conclusions were drawn.

From the point of view of development the hand consists of three rays, viz., radial, central and ulnar. Each carpal bone is also considered to belong to one of these rays as clearly indicated in Figure 11.

The development of the radial ray division of the carpal bones was found to be related to that of the radius, based on the analysis of four types of radial ray defects in our series.

The ulnar ray was confirmed to include the ulna, triquetrum, pisiform, hamate, a part of the capitate, the fourth and fifth metacarpals and the two ulnar fingers. The development of this ulnar division of carpal bones was also found to be related to that of the ulna in the same manner as seen in the radial ray. The central ray was confirmed to consist of the capitate, a part of the trapezoid, a part of the hamate, three central carpal bones and the three central fingers. In comparison with the other two divisions, carpal bones of this central ray division show a quite different mode of development. Here the development precedes from the distal part of the hand, as determined from various carpal bone anomalies in the cleft hand. An anomaly of the lunate was not detected in any patient with a central ray defect.

ACKNOWLEDGEMENT

Thanks are due to M. Ohara, Kyoto University, for assistance with the manuscript.

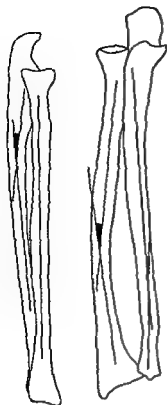


Figure 1 Diaphyseal angulation method of measurement In the a p projection the ulna has usually two curvatures Only the distal one was included In this case the angulation in the lateral projection of the radius is 0

method is in normal individuals about 12° or 6 per cent (coefficient of variation). Since mal position visible at the former site of the fracture could not be expected and was not found the shape of the radius and the ulna with regard to curvature was recorded as shown in Figure 1. Measurements of angulation obtained in this manner were used for a comparison between the injured and the uninjured forearms.

RESULTS

None of the patients had sought medical attention because of their forearms during the time interval between the healing of the fracture in childhood and the follow up examination. Only one had any complaints whatsoever. This patient felt some weakness of the forearm and hand

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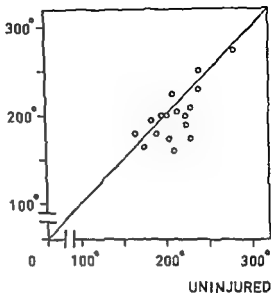


Figure 2 Pronation-supination deviation from the null hypothesis

Table 1 Pronation-supination in the fractured and the non fractured forearms

	Average	SD
Fracture	190°	$\pm 37^\circ$
Non fracture	214°	$\pm 27^\circ$
Difference 19°		

and had (compare below) the greatest limitation of range of motion of all those tested. In the entire group the range of pronation and supination motion was somewhat decreased in the previously fractured forearms and this decrease was significant. The difference was about 20° (Table 1). The distribution of pronation and supination in relation to the null hypothesis is also demonstrated in Figure 2.

The curvature of the ulna seen from the lateral aspect was significantly less in fractured arms but the difference was negligible. Otherwise there was no difference in the various angles which could

THE RANGE OF MOTION FOLLOWING FRACTURE OF THE SHAFT OF THE FOREARM IN CHILDREN

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Eighteen children with fracture of the shafts of the forearm were re-examined in adulthood. All fractures had primarily been displaced but reduced to a good position without residual axial or *ad latem* displacement. At follow up there was no sign of deformity in the radiograms of the two bones. However, the range of motion for supination and pronation was significantly decreased. This implies that factors other than residual deformity are responsible for this dysfunction.

Key words: fracture, forearm, diaphysis, deformity.

Accepted 23 vi 77

Hogstrom et al (1976) found that limitation of pronation and supination was a common finding after diaphyseal forearm fractures in childhood. The dysfunction was related to angulation caused by incomplete reduction of the fracture. This relationship, however, was weak with a large residual variance leaving most of the limitation unexplained. Therefore it was decided to investigate whether or not limitation of these movements could be found after fractures of the shafts of the forearm in childhood which had been properly reduced and which had healed in a good position.

MATERIAL AND METHODS

During the years 1954-1960 about 40 cases of diaphyseal fracture of the forearm in children

below the age of 13 were recorded. Of these 28 fulfilled the criteria that there had been a substantial initial fracture displacement and that this displacement had been reduced completely. Of these patients 18 (11 men and 7 women) volunteered for a follow up examination in 1976. In this group the primary dislocation evaluated in the pre-reduction radiogram as the maximum angulation in either anterior-posterior or lateral films of the forearm over age of radius and ulna was $29 \pm 12^\circ$. In addition in six of these patients there was an obvious *ad latem* dislocation of one or both bones. Rotational displacement was estimated on the same films from the alignment of the radius and from possible differences in the width of the shaft of the radius immediately proximal and distal to the fracture (Evans 1951). Only in two cases was there a noticeable rotational malposition. Closed reduction had been used in all instances.

The age at fracture was 8 ± 3 years and the age at follow up 27 ± 4 . The shortest interval was 16 years.

The follow up included a clinical and radiological examination. Any complaints of the patient were recorded and the pronation-supination was measured in a specially designed cradle in which the patient turned a handle with his elbow in a fixed position. The precision of this

Financial support was obtained from the Swedish Medical Research Council (project no. B 76 17X 2737 08A), the Greta and Johan Koefoed Foundation and the Alfred Österlund Foundation.

SURGICAL MANAGEMENT OF FRACTURE OF THE CAPITULUM HUMERI

SVEN COLLERT

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A follow up study of 20 patients operated upon for fracture of the capitulum humeri is reported. In 8 cases the fracture fragment was removed while in 12 others open reduction was performed. Open reduction gave the best results and is therefore recommended as the treatment of choice.

Key words: capitellum, capitulum humeri, fracture, treatment

Accepted 23 v 77

Fracture of the capitulum humeri (capitellum) occurs as an alternative injury to fracture of the caput radii as a result of a fall on the outstretched arm. It is, however, considerably less common. The relative frequencies are reported to be 1/6 (MacDonald & MacGoey 1959, Palmer 1961). Opinions on the preferred surgical management of this injury differ. Some (Gejrot 1932, Rhodin 1942, Watson-Jones 1955) recommend reduction of the dislocated fragment. Others (Smith 1954, Bohler 1956, Judet & Raynal 1957, Fowles & Kassab 1974, Alvarez et al 1975) believe removal of the fragment to be the best treatment. The present report evaluates and compares the results of these two alternative methods of treatment.

MATERIAL AND METHODS

The material consists of 20 consecutive patients operated upon for fracture of the capitellum at St Goran's Hospital or Södersjukhuset, Stockholm during the period 1966-1972. Of these 13 were women and 5 men who at the time of accident could be divided into the following age groups: 20-29 years one patient, 30-39, three 40-

49, five 50-59, three, and 60-69, eight patients. In seven cases only the capitellum or a portion of it was fractured (Type 1) (Figure 1). In the remaining 13 cases the fracture also involved the lateral portion of the trochlea (Type 2). The dislocated fragment always showed a volar and proximal displacement and sometimes a rotation amounting to as much as 90° (Figure 2). Chisel fracture of the capitulum radii occurred as a concomitant injury in three cases. All patients were examined by the author personally, and the examination was completed by x-rays of the elbow. The observation period was 1-2 years in three cases, 3-4 years in seven, 5-6 years in seven and more than 11 years in three cases.

Treatment

In eight cases treatment consisted of removal of the fragment and in twelve cases open reduction was performed. In seven of these cases the fragment was fixed with a Palmer pin and in the other five there was no internal fixation (Table 1). All operations were performed at the acute stage (within 10 days after accident) except in one case, which was first operated upon 1 year after injury, with extirpation of the fragment.

In those cases in which the fracture fragment was removed, active physiotherapy was begun immediately. The remainder were immobilized in plaster casts for 1-4 weeks postoperatively after which physiotherapy was begun.

be measured on the radiograms between fracture and non-fracture forearms (Table 2). It must therefore be concluded that the fracture had not changed the shape of the two forearm bones. The difference in the range of pronation and supination movement between the fracture and the control forearms was not related to the initial angulation or to whether or not there had been an initial *ad latem* dislocation. Also, limitation of pronation and supination was unrelated to the age at the time of fracture. In the two cases with rotational malposition the pronation and supination was decreased by 10° in one and by more than 15° in the other as compared with the uninjured side.

Table 2 Angulation difference between fractured and non-fractured forearms

	Radius	Ulna
Anteroposterior	0.4° ± 2.9°	0.1° ± 3.1°
Lateral	0.3° ± 4.9°	-1.4° ± 2.6°

One patient, a 26-year-old man, had sustained a fracture of the distal third of the diaphysis of the radius and the ulna at the age of 9 and a primary angulation of about 30° had been reduced completely. There were no radiological signs of deformity whatsoever at the time of follow-up. Nevertheless, this patient had a limitation of his range of motion of 120° and was the only patient to complain of residual symptoms.

DISCUSSION

The clinical findings in this study agree with those of Hogstrom et al (1976) in that even patients with a decrease in the range of pronation-supination motion of 50° had not noticed their dysfunction. This might be the reason why this has not been observed in the past. Hogstrom et al (1976) found a limitation of pronation and supination of about 25° following forearm fractures which had healed with a residual angulation of on the average 20°. In the present study the limitation of pronation and supination recorded at follow-up was almost as much. This implies that the contribution to this dysfunction of angulation of the two bones is of minor importance since completely reduced forearms which had healed without any malposition whatsoever still have a measurable and significant limitation of their range of pronation-supination motion. The importance of rotational deformity, however, could not be studied in this series since only two cases had been reduced with a noticeable residual rotational malposition.

REFERENCES

- Ivans F M (1951) Fractures of the radius and the ulna. *J Bone Jt Surg* 33 B, 550-561.
- Hogstrom H, Nilsson B F & Willner S (1976) Correction with growth following diaphyseal forearm fracture. *Acta orthop scand* 47, 299-303.

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Accepted 23 v 77

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Treatment

In eight cases treatment consisted of removal of the fragment and in twelve cases open reduction was performed. In seven of these cases the fragment was fixed with a Palmer pin and in the other five there was no internal fixation (Table 1). All operations were performed at the acute stage (within 19 days after accident) except in one case, which was first operated upon 1 year after injury, with extirpation of the fragment.

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REFERENCES

- IVARS I. M. (1951) Fractures of the radius and the ulna. *J. Bone Jt. Surg.* 33 B, 550-561.
- Hogstrom H., Nilsson B. J. & Willner S. (1976) Correction with growth following diaphyseal forearm fracture. *Acta orthop. scand.* 47, 299-303.

showed excellent or good results. In six type 2 fractures treated with open reduction results were excellent in two cases, good in two and poor in two cases. In all cases of excellent results exact anatomical position was achieved. In seven type 2 fractures treated with removal of the fragment results were good in four and poor in three cases.

Table 2 Results related to treatment and type of fracture

		Excellent	Good	Poor	Total
Removal of fragment	Type 1	0	1	0	1
	Type 2	0	4	3	7
Open reduction	Type 1	3	3	0	6
	Type 2	2	2	2	6
Total		5	10	5	20

Three patients were reoperated with excision of the radial head $\frac{1}{2}$ -1 year after the first operation because of severely impaired mobility. Two of these were originally treated by removal of the loose fragment and one by reduction. After reoperation the range of movement improved but all three remained in the 'poor result' group. A ray examination showed that in the majority of cases, regardless of treatment, there was some deformation of the capitellum. In none of the cases, however, was there any loose body in the joint or signs of secondary osteoarthritis.

DISCUSSION

This investigation shows that reduction of the fracture gives good results provided that a good anatomical position is achieved. This was the case in all five patients in the excellent group. It was suggested by Smith (1954) and Judet & Rignal (1957) that reduction of the fracture may result in avascular necrosis

and secondary osteoarthritis. No signs of complications of this type were seen in any of the cases in this study.

In nearly half of the cases the fracture was so stable after reduction that internal fixation proved unnecessary. No post-operative redislocation occurred.

Some authors (Rhodin 1942, Watson-Jones 1955, Bohler 1956) claim that closed reduction should always be tried first. An attempt at closed reduction was made in three cases in this series, but without success. If a good functional result depends on exact reduction, then open reduction would seem to be a better and safer method.

After extirpation of the fracture fragment a raw bone surface remains, which according to Watson-Jones (1955) tends to lead to capsular adhesions and restricted mobility. In this investigation all eight patients treated in this manner had restricted mobility. However, Alvarez et al. (1975) and others reported good results with this method. In those cases where an exact reduction is not achieved or where the fracture is comminuted, it is better to remove the fragment or fragments. Smith (1954) and others claim that there is a risk of lateral instability and a tendency to subluxation following removal of the fragment in fractures of type 2. In the present series all elbow joints were stable at follow-up, so that this risk seems to be small.

Johansson (1962) found rupture of the ulnar collateral ligament in 8 out of 13 cases of fracture of the capitellum. In the present material the ulnar collateral ligament was explored in one case because of instability and swelling and a total rupture was found and sutured. It is probable that restricted mobility following fracture of the capitellum is partly dependent on the extent of concomitant capsule and ligament injuries.

The results of the present investigation clearly indicate that open reduction of fracture of the capitulum humeri is a

Table 1 Treatment related to type of fracture

	Type 1	Type 2	Total
Removal of fragment	1	7	8
Open reduction + internal fix	2	5	7
Open reduct without int fix	4	1	5
Total	7	13	20

RESULTS

The majority of patients were pain-free or had only insignificant pain and evaluation of the results was therefore based on limitation of movement. The results were classified as follows: *Excellent* completely normal mobility without any subjective discomfort; *Good* limitation of extension not exceeding 30° and/or a range of flexion of at least 120°, normal pronation and supination; *Poor* limitation of mobility exceeding the above and/or restriction of pronation and supination.

The results are summarized in Table 2. Six out of seven type 1 fractures were treated with open reduction. They all

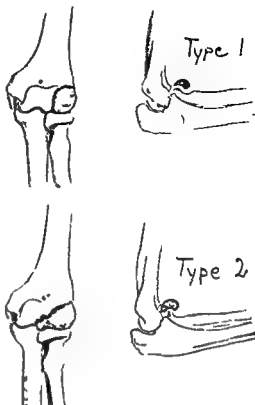


Figure 1 Types of fracture of capitulum humeri. Type 1 involves the capitulum only. Type 2 includes also part of the trochlea.

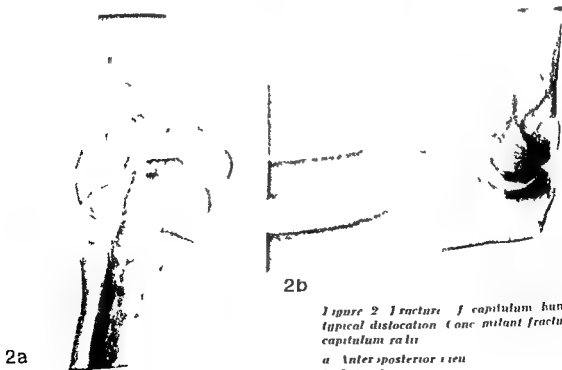


Figure 2 Fracture of capitulum humeri with typical dislocation. Concurrent fracture of capitulum radius.

a Anteroposterior view
b Lateral view

RESECTION OF THE ACHOMION IN THE TREATMENT OF PERSISTENT ROTATOR CUFF SYNDROME OF THE SHOULDER

JARL-ERIK MICHELSSON & GEORG BAKALIN

The Orthopaedic Hospital of the Invalid Foundation, Helsinki, Finland

Partial or complete excision of the acromion was performed in 23 patients (29 shoulders) with long standing pain in the shoulder typical of rotator cuff syndrome. There was no verified history of trauma in nine cases (13 shoulders), while injury was the cause of pain in 16 patients (16 shoulders) in nine shoulders there was a small and in two a large rupture of the rotator cuff. Twelve of the 13 non-traumatic shoulders became painless postoperatively and the pain was relieved in one. In the 16 traumatic shoulders the relief of pain was complete in six, partial in nine, and one remained unchanged. The condition was not aggravated in any of the cases. Mobility increased postoperatively in four cases and was in no case decreased by the operation. In this series the results were as favourable after partial as after complete excision of the acromion. Excision of the acromion alone or excision in combination with other procedures appears to be a promising method of treatment of patients with long standing rotator cuff syndrome.

Key words: acromion resection; supraspinatus syndrome; rotator cuff syndrome; painful arch syndrome; shoulder pain.

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The majority of patients with rotator cuff (supraspinatus, painful arch, impingement) syndrome of the shoulder recover either spontaneously or after conservative treatment. Patients with persistent pain have been operated upon applying various methods, e.g. partial (Smith-Petersen et al 1943, Darrach 1945, Neviaser 1961, Neer 1972) or complete excision of the acromion (Watson-Jones 1943, Armstrong 1949, Rossler 1959, Rose 1961, Hammond 1962, Sih 1964).

The aim of this study was to investigate the importance of the extent of excision of the acromion because the literature is somewhat controversial on this subject.

We also wanted to find out how the rotator cuff syndrome of different aetiologies and the mobility of the shoulder affected the results of the operation.

MATERIAL

The series consists of 23 patients with 29 shoulders with rotator cuff syndrome, operated upon at the Orthopaedic Hospital of the Invalid Foundation, Helsinki, during the period 1958-1970. The patients' ages at the time of operation ranged from 30 to 64 years, the average being 50 years. Of the non-traumatic cases five were female and four male, of the traumatic cases four were female and 12 male. The right shoulder only was affected in 14 cases, the left shoulder in seven and both shoulders in four (Table 1) and only one patient was left handed.

better method of treatment than removal of the loose fragment

REFERENCES

- Alvarez, E, Patel M R, Nimberg G & Pearlman, H S (1975) Fracture of the capitulum humeri *J Bone Jt Surg* 57 A, 1093-1096
- Bohler, I (1956) *The treatment of fractures* New York Grune and Stratton
- Fowles, J V & Kassab, M T (1974) Fractures of the capitulum humeri *J Bone Jt Surg* 56 A, 794-798
- Gejrot, W (1932) On intra articular fractures of the capitulum and trochlea of the humerus with special reference to the treatment *Acta chir scand* 71, 253-270
- Johansson, O (1962) Capsular and ligament injuries of the elbow joint *Acta chir scand* Suppl 287
- Judet, J & Raynal I (1957) Les fractures du capitellum ou décalotement de l'éminence capitata *Acta orthop belg* 22 5 22
- MacDonald J A & MacGoey, P I (1959) Fractures of articular portion of capitellum in adults (*canad med Ass J* 81 634)
- Milch J (1931) Unusual fractures of the capitulum humeri and the capitulum radii *J Bone Jt Surg* 12 882-886
- Palmer, I (1961) The validity of the rule of alternativity in traumatology *Acta chir scand* 121, 481-485
- Rhodin, R (1942) On the treatment of fracture of the capitellum *Acta chir scand* 86 475-486
- Smith F M (1954) *Surgery of the elbow* Springfield Illinois, Charles C Thomas
- Watson Jones, R (1955) *Fractures and joint injuries* Livingstone Edinburgh

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Table 3 Results after excision of the acromion in relation to pain in the various categories of injury in the traumatic group

Trauma and peroperative findings	Results				
	Painless	Improved	Unchanged	Impaired	Total
Partial rupture of supraspinatus only	2	3	1	—	6
Partial rupture of supraspinatus + rupture of the long head of π biceps	—	1	—	—	1
Dislocation of humerus + total supraspinatus rupture	1	1	—	—	2
Dislocation of humerus without visible rupture of tendons	—	1	—	—	1
Dislocation of acromioclavicular joint	1	—	—	—	1
War injury, shell splinters	—	1	—	—	1
Miscellaneous cases without injury to tendons	2	2	—	—	4
Total	6	9	1	—	16

its in the musculotendinous cuff in eight non-traumatic and two traumatic shoulders. Acromioclavicular arthrosis was clearly present in three shoulders: one non-traumatic and two traumatic. Dislocation of the acromioclavicular joint was observed in one shoulder.

Rotator cuff rupture. During the operation a small rupture of the rotator cuff was observed in nine shoulders: two non-traumatic and seven traumatic. A large rupture was found in two out of three shoulders that had become painful after dislocation of the humerus.

Operative procedure. The excision of the acromion was performed in sagittal projection, and complete extension (including the acromioclavicular joint) was performed in six shoulders (Tables 3 and 4). In nine out of the 11 shoulders with a rotator cuff tear this was repaired during operation. In three the tendon was fixed by sutures to the tuberculum majus humeri and in the remainder the tendon defect was merely sutured as well as possible to diminish the defect. The detached part of the deltoid muscle was refixed by sutures to the clavicle and the rest of the acromion.

Postoperative care. After the operation three extremities only were fixed in an abduction splint for about 2 weeks; the others were sup-

ported in a collar sling. Passive movements were usually begun during the first week post-operatively and the active exercises thereafter.

RESULTS

Pain. Twelve of the 13 non-traumatic shoulders became painless postoperatively and the pain was considerably relieved in one (Table 3). In the 16 traumatic shoulders the relief of pain was complete in six and marked in nine, while one remained unchanged (Tables 4 and 5). No aggravation was recorded in this series. Of the two patients with no tendon suture in connection with the acromion excision one was painless and the other was improved and of the nine patients with tendon sutures four were painless, four others improved and one unchanged.

Mobility. Postoperatively the range of movement was normal in 12 non-traumatic shoulders and slightly reduced in one (i.e., one improved, 12 unchanged).

Table 1 Side of operated shoulder in relation to aetiology (no of patients)

Side	Aetiology		Total
	Non traumatic	Traumatic	
Left	1	6	7
Right	4	10	14
Bilateral	4	—	4
Total	9	16	25

Table 2 Duration of pain before operation in relation to aetiology

	Aetiology	
	Non traumatic	Traumatic
Duration in years	$\frac{1}{2}$ -6	$\frac{1}{2}$ -17
Average	2.7	3.6

Pain in the shoulder had been experienced for a period of from half a year to 17 years the average being 3.3 years (Table 2). The majority of the patients had been conservatively treated

(physiotherapy, cortisone injections, local anæsthetics X-ray treatment) without success. The pain in the shoulder was in all cases accentuated on flexion and abduction of the humerus. A follow up examination was performed 3.5-15 years (average 6.5 years) after operation. There was no history of injury in nine cases (13 shoulders) while it was obvious that the pain had been caused by trauma in 16 cases (16 shoulders). In the latter group there were three cases of dislocation of the shoulder joint and one case of acromioclavicular dislocation. One patient had a history of slight shell splinter injury (Table 5).

Of the non traumatic patients six had light to moderate and one heavy physical work of the patients with trauma three had light six moderate and seven heavy physical work.

Preoperative clinical findings. In the non traumatic group the range of passive and active movement was normal before operation in 11 shoulders and somewhat reduced in two (Table 6). In the traumatic group the range of movement was normal in seven shoulders slightly reduced in two and markedly reduced in seven (Table 7). In the majority of patients with limitation of shoulder movement active abduction and flexion were the most affected.

Preoperative X-rays revealed calcified deposits

Table 3 Results in relation to pain and extent of excision of the acromion in non traumatic cases (no of shoulders)

Extent of excision of acromion	Results				Total
	Painless	Improved	Unchanged	Impaired	
Partial	11	1			12
Subtotal	1				1
Complete					—
Total	12	1			13

Table 4 Results in relation to pain and extent of excision of the acromion in traumatic cases (no of shoulders)

Extent of excision of acromion	Results				Total
	Painless	Improved	Unchanged	Impaired	
Partial	3	6			9
Subtotal	1				1
Complete	2	3	1		6
Total	6	9	1		16

Table 5 Results after excision of the acromion in relation to pain in the various categories of injury in the traumatic group

Trauma and peroperative findings	Results				Total
	Painless	Improved	Unchanged	Impaired	
Partial rupture of supraspinatus only	2	3	1	-	6
Partial rupture of supraspinatus + rupture of the long head of m biceps	-	1	-	-	1
Dislocation of humerus + total supraspinatus rupture	1	1	-	-	2
Dislocation of humerus without visible rupture of tendons	-	1	-	-	1
Dislocation of acromioclavicular joint	1	-	-	-	1
War injury, shell splinters	-	1	-	-	1
Miscellaneous cases without injury to tendons	2	2	-	-	4
Total	6	9	1	-	16

ite in the musculotendinous cuff in eight non-traumatic and two traumatic shoulders. Acromioclavicular arthrosis was clearly present in three shoulders, one non-traumatic and two traumatic. Dislocation of the acromioclavicular joint was observed in one shoulder.

Rotator cuff rupture. During the operation a small rupture of the rotator cuff was observed in nine shoulders, two non-traumatic and seven traumatic. A large rupture was found in two out of three shoulders that had become painful after dislocation of the humerus.

Operative procedure. The excision of the acromion was performed in sagittal projection, and complete excision (including the acromioclavicular joint) was performed in six shoulders, subtotal excision in two and partial excision in 11 (Tables 3 and 4). In nine out of the 11 shoulders with a rotator cuff tear, this was repaired during operation. In three the tendon was fixed by sutures to the tuberculum majus humeri and in the remainder the tendon defect was merely sutured as well as possible to diminish the defect. The detached part of the deltoid muscle was refixed by sutures to the clavicle and the rest of the acromion.

Postoperative care. After the operation three extremities only were fixed in an abduction splint for about 11 weeks, the others were sup-

ported in a collar sling. Passive movements were usually begun during the first week post-operatively and the active exercises thereafter.

RESULTS

Pain. Twelve of the 13 non-traumatic shoulders became painless postoperatively and the pain was considerably relieved in one (Table 3). In the 16 traumatic shoulders the relief of pain was complete in six and marked in nine, while one remained unchanged (Tables 4 and 5). No aggravation was recorded in this series. Of the two patients with no tendon suture in connection with the acromion excision one was painless and the other was improved and of the nine patients with tendon sutures four were painless, four others improved and one unchanged.

Mobility. Postoperatively the range of movement was normal in 12 non-traumatic shoulders and slightly reduced in one (i.e., one improved, 12 unchanged).

Table 6 Results in relation to mobility of the shoulder before and after excision of the acromion in the non-traumatic group (no of shoulders)

	Mobility			Total
	Normal	Slightly reduced	Markedly reduced	
Before operation	11	2	—	13
After operation	12	1	—	13

Table 7 Results in relation to mobility of the shoulder before and after excision of the acromion in the traumatic group (no of shoulders)

	Mobility			Total
	Normal	Slightly reduced	Markedly reduced	
Before operation	7	2	7	16
After operation	9	3	4	16

(Table 6) In the traumatic group the range of movement was normal postoperatively in nine shoulders, slightly reduced in three and markedly reduced in four (i.e. three improved, 13 unchanged) (Table 7) Thus the operation resulted in increased mobility in four shoulders and in no case was the range of movement further decreased by the operation

In this series the extent of the excision of the acromion did not influence the occurrence of pain nor the mobility of the shoulder (Tables 3 and 4)

There was no definite correlation between the age of the patient and the duration of the symptoms before operation and the results

There was no dislocation or subluxation of the glenohumeral joint postoperatively in our series

DISCUSSION

The aetiology and the mechanism of pain in the shoulder are not fully understood. A number of investigations (Codman

1934, Watson-Jones 1943, Wilson 1943, McLaughlin 1944, 1946, 1954, Armstrong 1949, Hammond 1962, Moseley 1969, Macnab 1971) have shown that a lesion of the tendon of the supraspinatus muscle or some other muscle belonging to the rotator cuff system may lead to the typical condition, the painful arch (supraspinatus) syndrome, which is characterized by pain, tenderness on palpation, muscle spasm and limitation of shoulder movement. The pain is usually elicited by activity or compression of the rotator cuff. Abduction and flexion of the humerus, in particular, often lead to painful compression of the rotator cuff between the head of humerus, the acromion and the acromioclavicular ligament. Excision of the acromion eliminates the compression of the rotator cuff caused by movements of the shoulder joint. Many authors consider complete excision of the acromion necessary to ensure successful results and to eliminate the risk of recurrence. The importance of excision of the anterior edge and undersurface of the anterior part of the

acromion which may cause impingement on the tendinous portion of the rotator cuff has been emphasized (Neer 1972). In the present series the results were as favourable after partial as after complete excision of the acromion. As regards the relief of pain the results were generally good and the condition was not aggravated postoperatively in any of the cases. Mobility was also improved after operation in some of the cases and there was no instance of postoperative impairment of mobility. In our series there was no dislocation and subluxation of the shoulder after the operation. Subsequently we have seen two other cases with a tendency to subluxation of the humeral head during normal activities after complete excision of the acromion. In these cases there was a large rupture of the capsule and of the rotator cuff both of which were not adequately reconstructed. It is probably important to reconstruct these structures and if they are still insufficient the acromion should not be excised completely.

Most patients with pain in the shoulder particularly those with the supraspinatus syndrome recover spontaneously or after physiotherapy. In the treatment of persistent symptoms of the supraspinatus group excision of the acromion appears to be a promising alternative.

REFERENCES

- Armstrong J R (1949) Excision of the acromion in treatment of the supraspinatus syndrome. *J Bone Jt Surg* 31 B 436-442.
- Codman P A (1934) *The shoulder*. The Author, Boston.
- Darrach W (1915) Surgical approaches for surgery of the extremities. *Amer J Surg* 67 118.
- Hammond G (1962) Complete acromiectomy in the treatment of chronic tendinitis of the shoulder. *J Bone Jt Surg* 44-A 494-503.
- Macnab I (1971) The painful shoulder due to rotator cuff tendinitis. *Br J Med* 1 54 367-374, 388.
- McLaughlin H L (1944) Lesions of the musculotendinous cuff of the shoulder I. The exposure and treatment of tears with retraction. *J Bone Jt Surg* 26 31-51.
- McLaughlin H L (1946) Lesions of the musculotendinous cuff of the shoulder III. Observations on the pathology, course and treatment of calcific deposits. *Ann Surg* 124 354-362.
- McLaughlin H L (1954) Calcified deposits in the subdeltoid bursa. *Bull rheum Dis* 4, 48-49.
- Moseley H F (1969) *Shoulder lesions*. 3rd ed. pp 68-74. M & S Livingstone Ltd, Edinburgh.
- Neer C (1972) Anterior acromioplasty for the chronic impingement syndrome in the shoulder. *J Bone Jt Surg* 54 A 41-50.
- Neviaser J (1961) Complete acromiectomy in the treatment of tendinitis of the shoulder. *J Bone Jt Surg* 43 A 1260.
- Rose R M (1961) Acromion resection for persistent painful shoulder. *J La med Soc* 113 451-455.
- Rössler H (1959) Zur Problematik der schmerzhaften Shultersperre. *Z Orthop* 92 233-255.
- Sih J (1954) Der Platz der Akromionresektion in der Behandlung der Periarthritis humero-scapularis. *Zbl Chir* 89 679-680.
- Smith-Petersen M N, Aufranc D E, & Larson C B (1943) Useful surgical procedures for rheumatoid arthritis involving joints of the upper extremity. *Arch Surg* 46 764-770.
- Wilson-Jones R (1943) *Fractures and joint injuries*. 3rd ed. p 418. F & M Livingstone Ltd, Edinburgh.
- Wilson C L (1943) Lesions of the supraspinatus tendon: degeneration, rupture and calcification. *Arch Surg* 46 307-325.

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EXTIRPATION OF TUMORS LOCATED NEAR THE THORACIC CAGE

A Method for Increasing the Margin of Healthy Tissue on the Deep Side of the Tumor

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When an aggressive tumor develops in a flat muscle near the thoracic cage the question may arise as to how achieve an adequate margin on the deep side of the tumor. This is especially the case if the tumor has recurred after a previous non radical operation. A method is described by which the external thoracic fascia, the external intercostal musculature, and the periosteum on the external surface of the ribs can be included in the specimen as a continuous wall of healthy tissue on the deep side of the tumor. This technique has been used in 11 patients, 9 of whom had undergone one or more inadequate operations earlier. Eight patients had a malignant tumor, three an extra abdominal desmoid. In one of the latter patients, in whom a recurrent tumor was adherent to rib periosteum the method was unsuitable. In the other patients the method appears to have been adequate for local control of the tumor.

Key words: chest wall, four quarter amputation, operative technique, soft tissue neoplasm, surgical treatment, thoracic neoplasms

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Malignant soft tissue tumors must be removed with a margin of healthy tissue on all sides. The quality of the margin decides how wide it must be. A tumor originating in a muscle tends to get an elongated shape growing as it does preferentially in the direction of the muscle fibers. Therefore, in the longitudinal planes of the muscle, the margin must be very wide, which often means removal of the whole muscle. In the transverse planes the margin need not be as wide providing the preformed fascial confinement of the tumor-bearing region is included in the specimen (Stener 1971). Even malignant soft tissue tumors tend

to respect preformed fibrous walls for a long time (Simon & Linneking 1976).

Tumors located near the thoracic cage present special problems. For radical removal of a tumor developed for instance in one of the broad muscles originating on ribs and inserting on the upper limb it may not be sufficient to excise the implicated muscle, including its fascia. There is often a need for increasing the margin of healthy tissue being removed on the deep side of the tumor. This is especially the case if the tumor has recurred after a non radical earlier operation.

The purpose of this paper is to describe

a method by which the external thoracic fascia, the external intercostal musculature, and the periosteum on the external surface of the ribs can be included in the specimen as a continuous wall of healthy tissue on the deep side of the tumor

ANATOMY

The following description of relevant anatomical details is based mainly on Grunt's Atlas of Anatomy (1962)

The thoracic cage is covered by the external thoracic fascia which extends from one rib to the next. The intercostal musculature can be divided into three layers (Figure 1). The *most superficial* consists of the external intercostal muscle (1) which extends from the costotransverse joints in the back to the costochondral junction in the front where it is replaced by the external intercostal membrane (2). The fibers of this muscle

and membrane are directed obliquely downwards forwards. The *middle layer* consists of the internal intercostal muscle (3) which extends from the sternum in the front to the junction of the middle and posterior thirds of the ribs in the back, where it is replaced by the internal intercostal membrane (4). The fibers of this muscle and membrane are directed obliquely downwards backwards. The *deepest layer* consists of the innermost intercostal muscle (5) which extends from the junction of the anterior and middle thirds of the ribs in the front to the angle of the ribs in the back. The fibers of the innermost intercostal muscle are directed obliquely downwards-backwards. The intercostal nerves and vessels run between the middle and the deepest layers where the latter is lacking they run close to the pleural membrane.

METHOD

When the thoracic cage has been exposed during the operation at a safe distance from the tumor the dissection is continued as illustrated in Figure 2. The periosteum of the rib chosen as the starting point for the dissection is incised along the border being most remote from the tumor site. It is then elevated as far as the insertion line of the external intercostal muscle and membrane on the opposite border. Once this muscle and membrane have been detached subperiosteally from the rib they are separated from the internal intercostal muscle and membrane as far as the next rib where they are again detached subperiosteally. The dissection is then carried on in this manner from rib to rib until the tumor region has been safely passed. In this way the external thoracic fascia, the external intercostal musculature and the periosteum on the external surface of the ribs will be included in the specimen as a continuous wall of healthy tissue on the deep side of the tumor.

The separation of the external intercostal muscle and membrane from the internal ones is facilitated by the different fiber directions of these muscles and membranes. Because the fibers of the external intercostal muscle and membrane are directed obliquely downwards forwards it is convenient when detaching this muscle and membrane from their rib insertions

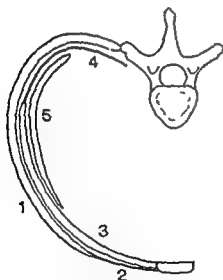


Figure 1. A line drawing representing the constituents of the three layers of intercostal structures. 1 = external intercostal muscle. 2 = external intercostal membrane. 3 = internal intercostal muscle. 4 = internal intercostal membrane. 5 = innermost intercostal muscle.

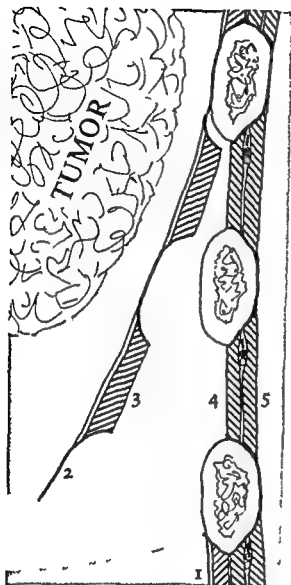


Figure 2 Schematic drawing demonstrating the method described for increasing the margin of healthy tissue being removed on the deep side of a tumor located near the thoracic cage 1 = external thoracic fascia 2 = periosteum of rib 3 = external intercostal muscle 4 = internal intercostal muscle 5 = innermost intercostal muscle

to proceed from behind forwards along the superior border of the rib and in the opposite direction along the inferior border. When making this dissection in the back it should be remembered that medial to the angle of the ribs where the innermost intercostal muscle is lacking the pleura comes next to the internal intercostal membrane.

CLINICAL MATERIAL

Since 1969 the technique described has been used for extirpation of a soft tissue tumor in 11 patients (Table 1). Their age ranged from 25 to 73 years. Eight patients had a malignant tumor, three a locally aggressive tumor (extra abdominal desmoid). Nine patients had undergone one or more non radical operations for the tumor before admission. Aspiration biopsy had indicated malignancy in the other two. None had signs of metastatic spread before operation.

The follow up time varied between 12 and 87 months in nine patients, the remaining two were operated upon recently.

One patient (Case 3), operated upon for a recurrent malignant fibroxanthoma in the left axilla (extended interthoracoscapular amputation) died after 15 months with pulmonary metastases, but the surgical field remained free from tumor.

One patient (Case 6), operated upon after a non radical removal of a malignant giant cell tumor of soft parts in the back (operation similar to that illustrated below in Case 8) was apparently free from tumor at follow up but has later developed pulmonary metastases.

One patient (Case 4), operated upon for a recurrence of an extra abdominal desmoid below the left axilla adherent to ribs, developed a new local recurrence after 30 months. A resection of the thoracic wall including the implicated ribs was then carried out and at follow up 27 months after this operation the patient showed no signs of recurrence.

The remaining six patients followed up were all well without any signs of recurrence or metastatic spread.

ILLUSTRATIVE CASES

Case 8 A 64 year old man had noticed a rapidly growing mass below the right scapular angle at the level of the eleventh rib. Under local anesthesia a tumor measuring $6 \times 4 \times 3$ cm was enucleated from the latissimus dorsi muscle. As it proved to be a pleomorphic liposarcoma the patient was referred for radical excision of the tumor region.

A rectangular incision of the skin was made at a minimum distance of 2.5 cm from the scar of the previous operation and two semicircular auxiliary incisions were made for wide exposure of the tumor region and to permit later on, primary suture of the wound without undue tension (Figure 3A). The specimen removed in one piece comprised the excised skin with underlying and surrounding subcutaneous fat

Table 1 Summary of clinical data on eleven patients operated on using the described technique

Case no.	Age	Sex	Histologic type	Site	Period of follow up (months)	Previous surgery	Aspiration biopsy	Local recurrence	Metastasis
1	60	Male	Extra abdominal desmoid	Pectoralis minor	82	-	+	-	-
2	41	Male	Pleomorphic liposarcoma	Pectoralis major	82	+	-	-	-
3	53	Male	Malignant fibrosarcoma	Latissimus dorsi	15 (died)	+	-	-	+
4	53	Male	Extra abdominal desmoid	Serratus anterior	57	+	-	+	-
5	25	Female	Extra abdominal desmoid	Pectoralis major	31	+	-	-	-
6	33	Male	Malignant giant cell tumor of soft parts	Latissimus dorsi	24	+	-	-	+
7	49	Male	Lipoma like liposarcoma	Latissimus dorsi	13	+	-	-	-
8	64	Male	Pleomorphic liposarcoma	Latissimus dorsi	12	+	-	-	-
9	73	Female	Malignant mesenchymoma	Pector spinae	12	-	+	-	-
10	54	Male	Malignant schwannoma	Pectus axillaris	1	+	-	-	-
11	59	Male	Myxoid and lipoma like liposarcoma	Between latissimus dorsi and serratus anterior	1	+	-	-	-

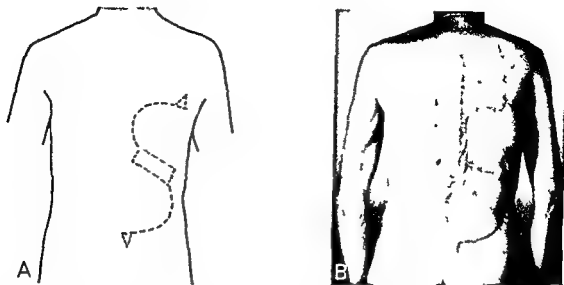


Figure 3 Case 8 A: Skin incisions. See text. B: Patient 6 months after operation.

(Figure 4C), the latissimus dorsi, the serratus posterior inferior, the quadratus lumborum, most of the erector spinae and some of the abdominal muscles and the periosteum of the four lowest ribs in continuity with the interlying external intercostal muscles (Figure 4D). Figure 4A shows the surgical field after removal of the specimen. Before the large S formed wound (Figure 4B) was sutured a small triangle of skin was excised at its upper and lower ends.

Histologic examination revealed that the specimen contained remnants of the tumor with in the earlier operation field which however had been removed with an adequate margin of healthy tissue on all sides.

At follow up 1 year after operation the patient was well without any signs of recurrence or metastases. The wound had healed nicely (Figure 3B). He was not inconvenienced by the loss of musculature.

Comment

In this case posteriorly the external intercostal muscles were separated from the internal intercostal membranes (cf. Figure 1). Medial to the angle of the ribs care had to be taken not to damage the pleura underneath these membranes. An almost identical operation in the same region was done in Case 6.

Case 11. A 73-year-old woman had for a few weeks noticed a firm painless mass in her back. On examination an elongated tumor whose size was estimated to be $13 \times 9 \times 5$ cm was found. It was located between the medial border of the left scapula and the spine. The long axis of the tumor had the same direction as the erector

spinae muscle. Aspiration biopsy revealed a malignant mesenchymal tumor. A radical extirpation was planned.

The incision of the skin and the subcutaneous fat was made so that the biopsy track became included in the specimen with an ample margin. When the trapezius, the rhomboid and the upper part of the latissimus dorsi muscles had been detached from the spinous processes it became clear that the tumor was free from the ribs; it appeared to have developed primarily in the erector spinae. This muscle was widely excised along with on the posterior side subcutaneous fat, parts of the trapezius, rhomboides major and latissimus dorsi muscles on the anterior side, the periosteum of four ribs in continuity with the interlying external intercostal muscles, and on the anteromedial side vertebral periosteum including the posteriorly protruding part of the left transverse process of three vertebrae (Figure 5C). Figure 5A shows the surgical field after removal of the specimen, the deep side of which is shown in Figure 5B. The tumor, which was never exposed during the operation, had been removed with an adequate margin of healthy tissue on all sides as revealed by serial sectioning of the specimen (Figure 5D). The histopathologic diagnosis was malignant mesenchymoma.

At follow up 1 year after operation the patient was well without any signs of recurrence or metastases.

Comment

This case illustrates how the described method of including rib periosteum and external intercostal muscles in a tumor specimen can be combined with inclusion of vertebral periosteum and

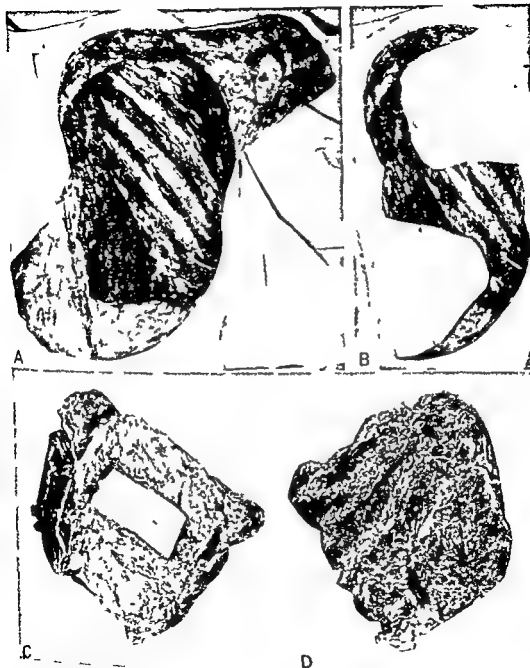


Figure 4. Case 8. Surgical field after removal of specimen (A) and before closure of wound (B). The specimen included a rectangular area of skin containing the scar and suture tracks after previous surgery (C) and on the deep side the perosteum of the first ribs in continuity with the overlying external intercostal muscles (D).

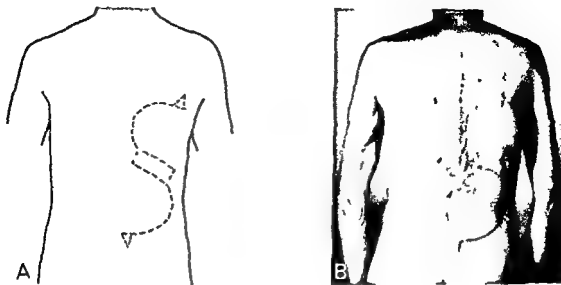


Figure 3 Case 8 A Skin incisions See text B Patient 6 months after operation

(Figure 4 C), the latissimus dorsi, the serratus posterior inferior, the quadratus lumborum, most of the erector spinae and some of the abdominal muscles and the periosteum of the four lowest ribs in continuity with the interlying external intercostal muscles (Figure 4 D). Figure 4 A shows the surgical field after removal of the specimen. Before the large S formed wound (Figure 4 B) was sutured a small triangle of skin was excised at its upper and lower ends.

Histologic examination revealed that the specimen contained remnants of the tumor with in the earlier operation field which however had been removed with an adequate margin of healthy tissue on all sides.

At follow up 1 year after operation the patient was well without any signs of recurrence or metastases. The wound had healed nicely (Figure 3 B). He was not inconvenienced by the loss of musculature.

Comment

In this case posteriorly the external intercostal muscles were separated from the internal intercostal membranes (cf Figure 1). Medial to the angle of the ribs care had to be taken not to damage the pleura underneath these membranes. An almost identical operation in the same region was done in Case 6.

Case 9 A 73 year old woman had for a few weeks noticed a firm painless mass in her back. On examination an elongated tumor whose size was estimated to be $13 \times 9 \times 5$ cm was found. It was located between the medial border of the left scapula and the spine. The long axis of the tumor had the same direction as the erector

spinae muscle. Aspiration biopsy revealed a malignant mesenchymal tumor. A radical extirpation was planned.

The incision of the skin and the subcutaneous fat was made so that the biopsy track became included in the specimen with an ample margin. When the trapezius, the rhomboidei and the upper part of the latissimus dorsi muscles had been detached from the spinous processes it became clear that the tumor was free from the ribs; it appeared to have developed primarily in the erector spinae. This muscle was widely excised along with on the posterior side subcutaneous fat parts of the trapezius, rhomboideus major and latissimus dorsi muscles. On the anterior side the periosteum of four ribs in continuity with the interlying external intercostal muscles and on the anteromedial side vertebral periosteum including the posteriorly protruding part of the left transverse process of three vertebrae (Figure 5 C). Figure 5 A shows the surgical field after removal of the specimen, the deep side of which is shown in Figure 5 B. The tumor which was never exposed during the operation had been removed with an adequate margin of healthy tissue on all sides as revealed by serial sectioning of the specimen (Figure 5 D). The histopathologic diagnosis was malignant mesenchymoma.

At follow up 1 year after operation the patient was well without any signs of recurrence or metastases.

Comment

This case illustrates how the described method of including rib periosteum and external intercostal muscles in a tumor specimen can be combined with inclusion of vertebral periosteum and

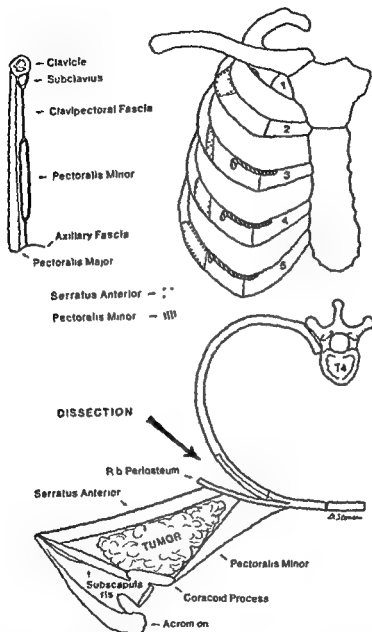


Figure 6 Case 10 Schematic drawings illustrating principle behind extended interthoracoscapular amputation (also completed in bottom figure) Rib periosteum in continuity with the external thoracic fascia and external intercostal muscles is being included in the specimen within the field; here the serratus anterior and the clavipectoral fascia (top left) including the subclavius and pectoralis minor are attached to the thoracic wall (top right) The room in which the tumor grows will thereby be removed unopened (cf. rib 5 in top right and bottom figures)

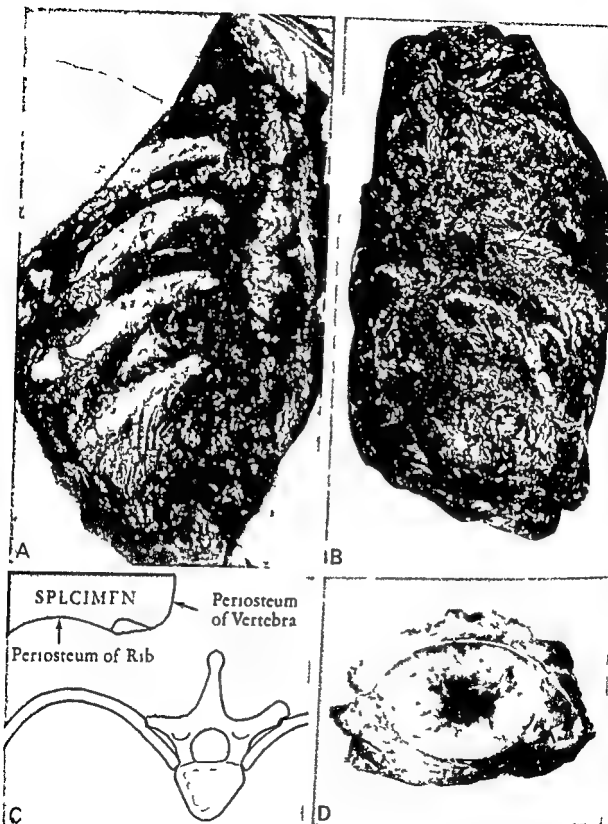


Figure 5 (Case 9) A: Surgical field after removal of specimen B. B: Post-operative specimen. C: Schematic drawing showing that the specimen included costal and vertebral periosteum and the posteriorly protruding part of the left transverse process. D: Transverse section of specimen B. Arrow indicates bottom medial margin, right arrow indicates border between tumor and claspings.

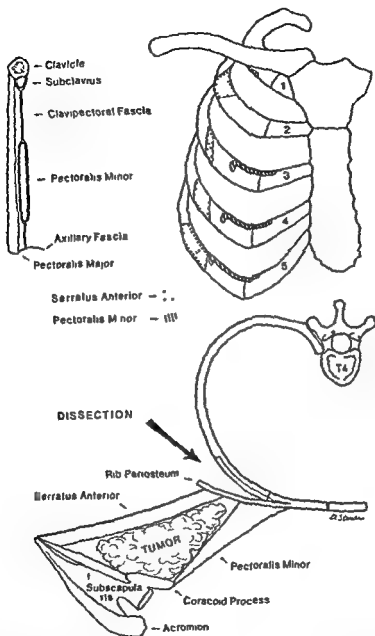


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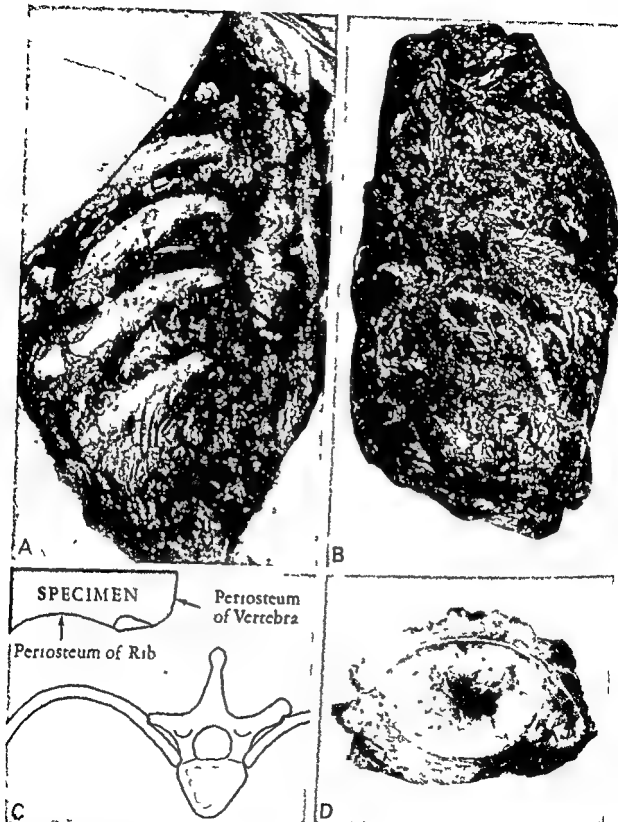


Figure 5 Case 9 A Surgical field after removal of specimen B. D of specimen C. Schematic drawing showing that the specimen included costal and vertebral periosteum and the posteriorly protruding part of the left transverse vertebral processes. D Transverse section of specimen D. Deep margin bottom medial margin right. Arrow indicates border between tumor and vertebral spine.

recurred or an extended excision is called for after a previous non radical operation. The same technique can be used for increasing the margin when a four quarter amputation is done (Cases 3 and 10). Nine of our eleven patients had previous operations, only two underwent a primary operation.

The technique described should be used only when the tumor is mobile in relation to the ribs. The only local recurrence in our series occurred in a patient who underwent the operation for a recurrent extra abdominal desmoid which was adherent to ribs (Case 4). In two patients operated upon for recurrent tumors pulmonary metastases occurred within 2 years but no signs of local recurrence appeared. The fact that distant

metastases develop does not indicate the method used for local control of the tumor as long as the primary site remains free from recurrence (Bowden & Booher 1958).

REFERENCES

- Bowden L. & Booher H. J. (1958) The principles and technique of resection of soft parts for sarcoma. *Surgery* 44 963-977.
- Craut J. C. B. (1962) *An atlas of anatomy* 5th ed. The Williams & Wilkins Co. Baltimore.
- Vaseley H. F. (1957) *The forequarter amputation*. E. & S. Livingstone Ltd., Edinburgh.
- Simon W. A. & Feneking W. F. (1976) The management of soft tissue sarcomas of the extremities. *J Bone Jt Surg* 58 A 317-327.
- Stener B. (1971) Amputation through the lower thigh with removal of the adductor and hamstring muscles. *Clin Orthop* 80 133-138.

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parts of the spine when the location of the tumor calls for this to be done

Case 10 A 54-year-old man was admitted with a large recurrence of a malignant Schwannoma in the right axilla. He suffered severe pain and the arm, which was paralysed and edematous, was quite useless. Radiotherapy (6000 rad) had been given without much benefit. An extended interthoracoscaphular amputation was performed. The extension beyond standard is illustrated in Figure 6. Instead of detaching the serratus anterior from the scapula and leaving it with the patient, this muscle was included in the specimen as it constituted the medial wall of the room occupied by the tumor. The anterolateral wall of this room was the clavipectoral fascia with the muscles it includes: the subclavius and pectoralis minor (top left in Figure 6), and the posterolateral wall was the subscapularis muscle. Between the lines along which the serratus anterior and the pectoralis minor are attached to the thorax (top right in Figure 6) the tumor-containing room was limited directly by the external thoracic fascia with underlying ribs and external intercostal muscles. So, in order to remove this room unopened and thereby increase the margin of healthy tissue being included in the specimen, the external thoracic fascia, the periosteum of the first, second, third and fourth ribs, and the external intercostal muscle and membrane of the first, second, third, and fourth intercostal spaces were removed within an area that included the rib attachments of the serratus anterior and pectoralis minor (Figure 7, cf Figure 6 top right). The pectoralis major was also included in the specimen. The postoperative course was uneventful, the patient was able to leave the hospital after 4 days.

Macro- and microscopic study of the surgical specimen indicated that the tumor had been radically removed.

When last seen 1 month after operation, the patient was apparently free from tumor. Being a Greek citizen domiciled in Greece, he has not been available for later follow-up examination.

Comment

The same type of extended interthoracoscaphular amputation was carried out in Case 3. In the standard type of "four quarter" amputation (e.g. Mosley 1957) the serratus anterior is left with the patient on the thoracic wall. This is not adequate when the operation is done for a malignant tumor developing in the axilla, for instance, a leiomyosarcoma originating in the axillary vein or, as in Case 10, a malignant Schwannoma originating in the axillary nerve plexus. In such cases, the whole serratus anterior should be included in the surgical specimen and

an extra safety margin is obtained, without significant cost for the patient, by including rib periosteum and external intercostal muscles as described in Figure 6.



Figure 7 Case 10. Anterolateral aspect of thoracic wall after extended right interthoracoscaphular amputation (cf Figure 6). Horizontal arrows indicate the line anterior to which the external thoracic fascia, the periosteum of the four uppermost ribs and the external intercostal muscle and membrane of the four uppermost intercostal spaces have been removed en bloc with the specimen. The internal intercostal muscles have been exposed within this area. Notice the difference in fiber direction between the external and internal intercostals. Vertical arrow indicates the costochondral junction of the third rib (cf Figure 6 top right).

DISCUSSION

The described operative technique is indicated when an aggressive soft tissue tumor (malignant or only locally aggressive) develops within a flat muscle of the thoracic wall, especially if the tumor has

recurred or an extended excision is called for after a previous non radical operation. The same technique can be used for increasing the margin when a four-quarter amputation is done (Cases 3 and 10). Nine of our eleven patients had previously been operated upon, only two underwent a primary operation.

The technique described should be used only when the tumor is mobile in relation to the ribs. The only local recurrence in our series occurred in a patient who underwent the operation for a recurrent extra abdominal desmoid which was adherent to ribs (Case 4). In two patients, operated upon for recurrent tumors, pulmonary metastases occurred within 2 years, but no signs of local recurrence appeared. The fact that distant

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- Grant, J. M. B. (1962) *An atlas of anatomy* 5th ed. The Williams & Wilkins Co., Baltimore.
- Hosley II J. (1937) *The forequarter amputation* 1 & II Livingstone Ltd., Edinburgh.
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THE ARTERIAL SUPPLY OF THE ODONTOID PROCESS OF THE AXIS

BO ALTHOFF & IAN F. GORDON

Department of Orthopaedic Surgery II, University of Göteborg, Göteborg, Sweden

A study has been carried out of the arterial supply of the odontoid process of the axis. Among the arterial sources there are paired anterior and posterior ascending arteries arising from the vertebral artery. Arteries penetrate into the odontoid process at its base from both the anterior and posterior ascending arteries. A transverse arterial arcade is formed above its top by the anastomosing anterior and posterior ascending arteries. In this investigation it was demonstrated that a branch of the ascending pharyngeal artery (from the external carotid artery) joined this arcade after passing through the canalis hypoglossi of the occipital condyle. Moreover, there were inferior and superior horizontal arteries apparently coming from the internal carotid artery, which supplied the odontoid process. It was shown that the superior horizontal arteries penetrated the anterior atlanto-occipital membrane and ran across to the supraodontoid arterial arcade. There were also arteries which reached into the odontoid process via the accessory and apical ligaments. Vessels described—but not demonstrated—to reach the odontoid process via the alar ligaments could not be observed in this investigation. It was shown that inside the odontoid process the arteries formed a rich anastomosing network. The odontoid process of the axis is thus in the centre of a dense arterial network.

Key words: odontoid process, arterial supply, paired ascending arteries, supraodontoid arterial arcade, intrascapular anastomotic arterial network.

Accepted 27 VII 77

The odontoid process has a stabilizing effect on the function of the atlanto-axial articulation. This stability is jeopardized in fractures of the odontoid process, but a delayed or failed bony union need not necessarily give rise to any symptoms. Schatzker et al (1971) have reported a frequency of non-union (pseudarthrosis) in 64 per cent and Blockley & Purser (1956) in 63 per cent. Lower frequencies have been reported by Amies & Anderson (1956) who found a rate of pseudarthrosis of 5 per cent which was also found by Bohler (1965). There are also reports

(Nachemson 1960, Anderson & d'Alonzo 1974) with non-union frequencies of the order of 44 per cent and 26 per cent. The difference between the reported extremes of 64 per cent and 5 per cent appears to be due to the technique of examination which in the high frequency series includes tomography and radiography of the cervical spine in flexion-extension.

The reason for non-union has been debated (Nachemson 1960, Schatzker et al 1971). It is argued that the vascular supply becomes disturbed to an extent that revascularization does not occur.

satisfactorily. An impairment in healing follows. It has been suggested that in so-called low fractures, i.e. fractures through the base of the odontoid process, no vital vessels become injured and thus healing occurs uneventfully (Schatzker et al 1971, Bailey 1974). In high fractures however, the large vessels reaching the odontoid process via the accessory ligaments become injured and it has been postulated that this may impair circulation to such an extent that non union of an odontoid fracture ensues. Moreover, the opinion has been advanced that the vascular supply to the odontoid process is so poor in general that odontoid fractures consequently heal badly (Schmorl 1971, Bailey 1974). The pertinent problem, therefore, seems to be to analyse in more detail the vascular arrangement of the odontoid and furthermore relate the observations to the most common localizations of odontoid fractures.

Therefore the aim of this investigation was

- 1) to make a detailed study of the arteries surrounding, penetrating into and running in the odontoid process and
- 2) to produce experimental fractures and correlate the anatomy of arteries to the fractures obtained. This latter part of the investigation will be reported separately.

ANATOMY

Embryonal development

Between the twentieth and twenty fourth fetal week two laterally situated ossification centres appear (Figure 1). These unite at birth. About 2 years later an ossification centre appears on top of the fused lateral centres (Figure 1). Between the odontoid process and the remaining axis there is a cartilage plate which becomes ossified between 16 and 20 years of age. In the individual case the cartilage plate may however remain into adulthood.

During the second decade there is a fusion of the apical ossification centre with the two lateral

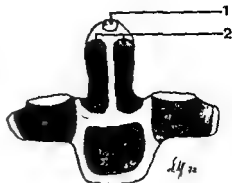


Figure 1 Embryonal development

- 1 Apical ossification centre
- 2 Lateral ossification centres

Ligaments

The odontoid process is important for the stability of the atlanto axial articulation. Its position in relation to the posterior facet of the anterior part of the atlas is secured by the strong transverse ligament running posterior to the odontoid. The accessory ligaments arise from the massa lateralis of the atlas and insert into the lateral aspect of the base of the odontoid process. The apical ligament arises from its tip and inserts into the anterior rim of the foramen magnum (Figure 2). There are two more ligaments—the alar—which arise posterolaterally from the odontoid and insert into the occipital condyles.

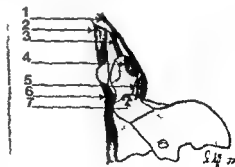


Figure 2 Ligaments around the odontoid process

- 1 Tectorial membrane
- 2 Anterior atlanto occipital membrane
- 3 Apical ligament
- 4 Alar ligament
- 5 Transverse ligament
- 6 Anterior longitudinal ligament
- 7 Accessory ligament

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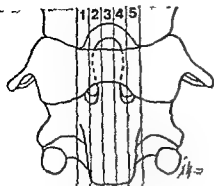


Figure 3a Longitudinal in sagittal plane

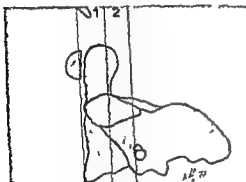


Figure 3b Longitudinal in frontal plane

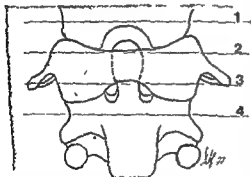


Figure 4c Transverse in horizontal plane

Figure 4 Sections of axis used for preparation according to the Spalteholz method

The contrast medium was injected into the common carotid artery and/or the vertebral artery. Three specimens were injected in both common carotid arteries and both vertebral arteries via four parallel coupled catheters. One specimen was filled through one common carotid artery only and two through one common carotid artery and one ipsilateral vertebral artery. The

injection was stopped when the white contrast medium was seen to appear either in the intercostal arteries or when the skin blanched. The filling pressure was that of manual compression of a 10 cm³ injection syringe. The filling procedure lasted for some 30 minutes. All arteries through which contrast medium leaked were tied. Following the filling procedure the cervical column and part of the base of the skull were excised and some contrast medium was seen to disappear from the carotid and vertebral arteries before it had adhered to the vessel walls.

The specimens were frozen and once hardened by the freezing procedure they were cut in longitudinal sections in both the sagittal and frontal planes (Figure 4a, b). Horizontal sections (Figure 4c) were also made. Each individual section was then x-rayed. A particular soft tissue technique also used for mammography was employed (Mammodiagnost, Philips). Film focal distance 30–35 cm, exposure 20 kV, 0.2–1 s Kodak film (Industrex C8) was used.

Following radiography the sections were prepared according to the Spalteholz technique (Spalteholz 1914) by which they were made translucent. This technique permits a three-dimensional study of the course of the arteries.

Once prepared by the Spalteholz technique the specimens were x-rayed a second time. More information regarding the distribution of the arteries was thus obtained. The Spalteholz technique involves decalcification which makes the arteries stand out more clearly.

RESULTS

In this investigation previous observations that the odontoid process receives its arterial supply via a system of longitudinal (ascending) and horizontal arteries could be confirmed. The paired anterior and posterior ascending arteries arose from the vertebral artery. The paired horizontal arteries apparently came from the internal carotid artery. In this investigation difficulties arose in exactly verifying the origin of the horizontal arteries as the contrast medium in most specimens had disappeared during the excision but the contrast medium covered the wall of the internal carotid artery in many instances and there was a direct connection between the wall and the horizontal arteries.

The anterior atlanto occipital membrane runs from the anterior lamina of the atlas to the base of the skull (Figure 2)

Main arteries in the odontoid region (Figure 3)

Adjacent to the odontoid process there are two main arteries, the internal carotid artery and the vertebral artery. The internal carotid artery runs antrolaterally in a cephalad direction and enters the skull through the foramen caroticum. The vertebral artery passes through the foramina transversaria of the cervical vertebrae and curves over the posterior lamina of the atlas. It then continues into the skull through the foramen magnum.

Close to the internal carotid artery there is the ascending pharyngeal artery, a branch of the external carotid artery.

Arteries to the odontoid process

Review of the literature. Only a few publications have been presented on the vascular supply of the odontoid process and there is a lack of uniformity in the descriptions. Schatzler et al (1971, 1975) described two main vascular sources. One was derived from so-called central arteries which entered the odontoid at its base and then ran in a cephalad direction inside its body. The other source was described in a schematic drawing showing arteries which from the massa lateralis of the atlas reached the odontoid via the accessory ligaments. Moreover it was suggested that vascular connections

existed at the insertions of the alar and apical ligaments. In the illustrations it is not conclusively demonstrated that these arteries actually penetrate into the odontoid process. Arteries were demonstrated within the odontoid process but it was impossible to show with certainty what areas of the dens were supplied by these vessels (through the apical and alar ligaments) or whether any anastomoses existed between the vessels which entered the dens through the apical and alar ligaments and the central and peripheral arteries (Schatzler et al 1971).

Schiff & Parle (1973) demonstrated a regular vascular pattern around the odontoid. Three main groups of vessels were described:

- 1) anterior ascending arteries
- 2) posterior ascending arteries and
- 3) cleft perforators (horizontal arteries)

The latter arose from the internal carotid artery and anastomosed with the anterior ascending arteries at the odontoid base. The anterior and posterior ascending arteries which appeared in pairs arose from the vertebral artery. These arteries assembled in a vascular arcade on the top of the odontoid. The anterior ascending arteries gave branches to the anterior aspect of the vertebral body of the axis to the base of the odontoid process and to its anterolateral surface. The posterior ascending arteries gave branches to the posterior aspect of the vertebral body of the axis. Further, Schiff & Parle (1973) described small holes on the surface of the odontoid and concluded that these were places of entrance for the arteries. No arteries were demonstrated within the odontoid process.

MATERIAL AND METHODS

The material for this investigation consisted of six human cadaver cervical columns. The individuals had died from causes not related to disease in the vascular system. Their ages were 62, 65, 67, 67, 70, 76 years respectively. There were two women and four men. All specimens were injected *in situ* with a contrast medium intra arterially. On excision the specimen contained the cervical column with the base of the skull.

The contrast medium consisted of a mixture of two parts 10 per cent formaldehyde and one part Micropaque. The injections were given according to Mullinger & Trueta (1970). 36-48 hours following death Mullinger & Trueta (1970) demonstrated that by injecting vessels 36-48 hours post mortem during which time the capillary bed is destroyed by autolysis—the contrast medium does not pass over to the veins.

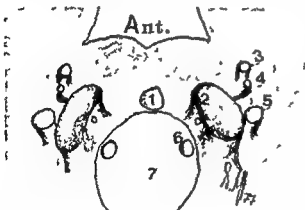


Figure 3. Main vessels just below the skull base in relation to the odontoid process and occipital condyles. Seen from below and posteriorly.

- 1 Odontoid process
- 2 Occipital condyle
- 3 Internal carotid artery
- 4 Ascending pharyngeal artery
- 5 Internal jugular vein
- 6 Vertebral artery
- 7 Foramen magnum

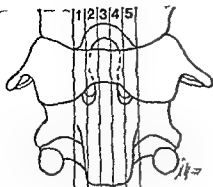


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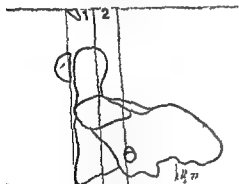


Figure 4b Longitudinal in frontal plane

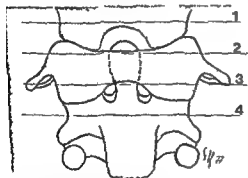


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Figure 5 Anterior aspect of the atlas and axis with arteries

- 1 Apical arcade
- 2 Posterior horizontal artery
- 3 Superior anterior horizontal artery
- 4 Inferior anterior horizontal artery
- 5 Anterior ascending artery
- 6 Vertebral artery

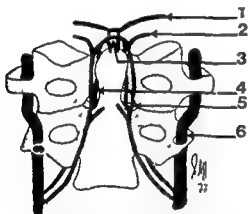


Figure 6 Posterior aspect of the body of the axis odontoid process and massa lateralis of the atlas with the lamina of the atlas and axis cut

- 1 Superior anterior horizontal artery
- 2 Posterior horizontal artery
- 3 Apical arcade
- 4 Anterior ascending artery
- 5 Posterior ascending artery
- 6 Vertebral artery

Paired anterior ascending arteries (Figures 5, 7 and 10)

These arteries branched off from the vertebral arteries immediately caudal to the axis. Their course was cephalad on the anterolateral surface of the axis and near the base of the odontoid process

each artery gave a branch which penetrated into the odontoid within which it then ran posteriorly and cephalad branching eventually into a network of fine arteries.

The anterior ascending arteries continued their course on the anterolateral surface of the odontoid and over the apex of this they joined and, anastomosing also with branches from the posterior ascending arteries, they here formed the apical arcade.

Paired posterior ascending arteries (Figures 6, 7, 10 and 11)

The posterior ascending arteries branched off from the vertebral arteries at the same level as the anterior ascending arteries. The posterior ascending artery ran cephalad on the posterolateral surface of the axis giving off branches to the body of this vertebra. At the base of



Figure 7 Sagittal section through the upper cervical spine. Radiograph of Spalteholz preparation (cf Figure 4a no 1 slice thickness 5 mm)

- 1 Anastomosing artery between the superior anterior horizontal artery and the apical arcade
- 2 Part of the apical arcade
- 3 Posterior ascending artery
- 4 Part of the anterior ascending artery



the picture Seen from above and posteriorly

- 1 Posterior ascending artery
- 2 Branch from the posterior ascending artery which runs along the accessory ligament to the lateral aspect of the odontoid base where it
- 3 penetrates the bone and divides into an arterial network.
- 4 Anterior ascending artery
- 5 An anterior artery penetrating into the odontoid process
- 6 Inferior anterior horizontal artery

the odontoid process one branch turned off and slightly caudad to the transverse ligament it penetrated into the odontoid within which it then divided into a number of small branches. Each of the paired posterior ascending arteries also gave off one branch which ran along the accessory ligament to the insertions laterally on the base of the odontoid where it penetrated into the bone. The posterior ascending arteries continuing in a cephalad direction passed posterior to the alar ligaments on top of which they turned medially and anteriorly. Joining the apical arcade they contributed to the formation of a vascular network round the tip of the odontoid and the alar ligaments. There were thus anastomoses connecting all the four ascending arteries. From this apical network branches were given off which descended into the odon-

toid within which further divisions occurred.

In this investigation it proved impossible to demonstrate any vessels penetrating into the odontoid process within the circumscribed region of the insertion of the alar ligaments.

Anterior horizontal arteries (Figures 5, 6, 7 and 8)

These vessels, two on each side, one inferior and one superior, ran horizontally on the anterior surface of the atlas. The inferior horizontal arteries anastomosed under the anterior lamina of the atlas with the ipsilateral anterior ascending artery. The superior horizontal arteries anastomosed with each other in the midline, and moreover, gave off branches which penetrated the atlanto-occipital membrane and established contact with the apical vascular network.

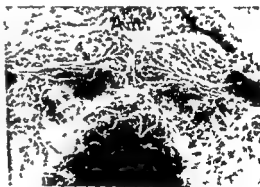


Figure 9 Horizontal section through the uppermost part of the cervical spine. Radiograph of Spalteholz preparation (cf Figure 4c no 1 slice thickness 12 mm) Seen from above and posteriorly

- 1 Internal carotid artery
- 2 Posterior horizontal artery (branch from the ascending pharyngeal artery)
- 3 Apical arcade
- 4 " "
- 5 " "
- 6 Capsular artery

Posterior horizontal arteries

(Figures 5, 6 and 9)

These arteries branching off from the ascending pharyngeal artery and running horizontally through the canalis hypoglossi of the occipital condyle at the level of the foramen magnum turned anteriorly and downwards and reached the apex of the odontoid process where they linked up with the apical vascular network.

Intraosseous anastomoses

(Figures 8, 10 and 11)

The arteries entering the odontoid process at its base anastomosed inside the odontoid with those arteries entering the odontoid at its apex. The interior of the odontoid process was the site of a rich anastomotic network of arteries.



Figure 10 Sagittal section through the odontoid process. Radiograph of Spalteholz preparation (cf Figure 4a no 3 slice thickness 5 mm)

- 1 Transverse section through the apical arcade
- 2 Apical artery penetrating into the odontoid process
- 3 An anterior artery penetrating the base of the odontoid process. Note the rich anastomosing network within the odontoid process and the anastomosing arteries between the apical and basal arteries



Figure 11 Frontal longitudinal section. Radiograph of Spalteholz preparation (cf Figure 4b no 1, slice thickness 10 mm)

- 1 An anterior artery penetrating the base of the odontoid process dividing into a fine anastomosing network
- 2 Anastomosing artery between the basal and apical arteries
- 3 and 4 Arteries penetrating the apex

There were arteries running along with the accessory and apical ligaments penetrating into the odontoid process. No arteries could be seen to run into the bone from the interior of these ligaments. Vessels from the apical arcade ran along the alar ligament without penetrating the odontoid bone.

DISCUSSION

From this investigation it has thus become evident that the odontoid process is in the centre of a rich network of arteries. Arteries were seen to penetrate into the odontoid around its base and at its apex. Vascular connections were demonstrated between ligament and bone except in the case of the alar ligaments. No arteries could be observed to traverse into the odontoid at the insertions of these ligaments. The failure to demon-

strate this may simply be a matter of technique and be related to the contrast medium used. However, it should be mentioned that a good filling of arteries was present in the arteries around the ligament as well as in the intraosseous area bordering the zone where the ligament inserts. In the translucent specimens it was impossible to detect any arteries and random histologic sections have not revealed any signs of vascular supply in this special region of ligamentous attachment. On the other hand, vascular connections were observed between the inside of the odontoid process and the vessels running along the apical and accessory ligaments. In studies of the vascular supply between ligaments and bone it has previously been demonstrated (Moseley & Goldie 1963, Peterson et al 1974, Björkstén 1976, personal communication) that vascular connections exist and the present observations coincide with those made in previous investigations.

The arterial arcade above the odontoid process has previously been described to have its origin in the anterior and posterior ascending arteries. In this investigation, however, it was demonstrated that the arcade receives arterial branches from other sources as well, such as, for example, the ascending pharyngeal artery, a branch of the external carotid artery, and those arteries, apparently branches of the internal carotid artery, which penetrate the membrana atlanto-occipitalis. Thus, the intraosseous arterial supply of the odontoid process is not entirely dependent on the anterior and posterior ascending arteries. This investigation has made clear that in cases of high odontoid fractures with or without interfragmentary dislocation the arterial supply need not necessarily be damaged to an extent that the superior

part of the odontoid process loses its blood supply as there are sources other than the anterior and posterior ascending arteries. This problem is the subject of further study.

REFERENCES

- Ames F W & Anderson F W (1956) Fracture of the odontoid process. *Arch Surg* 72 377-393.
- Anderson J D & Alonzo R T (1974) Fracture of the odontoid process of the axis. *J Bone Jt Surg* 56 A 1663-1674.
- Bailey H W (1974) *The cervical spine*. Febiger Philadelphia.
- Blockley N J & Purser D W (1958) Fracture of the odontoid process of the axis. *J Bone Jt Surg* 38 B 794-817.
- Bohler J (1975) Fractures of the odontoid process. *Trauma* 5 336-391.
- Gray's Anatomy Ed Davis D V (1962) p 770. Longmans Green and Co Ltd London.
- Moseley F H & Goldie I (1963) The arterial pattern of the rotator cuff of the shoulder. *J Bone Jt Surg* 45 B 780-789.
- Mullinger G L & Trueta J (1970) The blood supply of the talus. *J Bone Jt Surg* 52 B 160-167.
- Nachemson A (1960) Fracture of the odontoid process of the axis. *Acta orthop scand* 29 185-217.
- Peterson L, Goldie I & Lindell B (1974) The arterial supply of the talus. *Acta orthop scand* 43 260-270.
- Schatzker J, Rorabeck C H & Waddell J P (1971) Fracture of the dens (odontoid process): An analysis of thirty seven cases. *J Bone Jt Surg* 53 B 392-405.
- Schatzker J, Rorabeck C H & Waddell J P (1974) Non union of the odontoid process. *Can Orthop* 108 127-137.
- Schiff D L & Parke W W (1973) The arterial supply of the odontoid process. *J Bone Jt Surg* 55 A 1450-1456.
- Schmorl G (1971) *The human spine in health and disease*. Ed Junghans H. 2nd Amer edn. Ed Basemann F F. Crune & Stratton New York and London.
- Spalteholz H V (1914) *Lehrbuch des Durchsichtsmachen von menschlichen und tierischen Präparaten* (zweite Auflage). S. Hirzel Leipzig.

Posterior horizontal arteries

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These arteries branching off from the ascending pharyngeal artery and running horizontally through the craniis hypoglossi of the occipital condyle at the level of the foramen magnum turned anteriorly and downwards and reached the apex of the odontoid process where they linked up with the apical vascular network.

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- 1 Transverse section through the apical arcade
- 2 Apical artery penetrating into the odontoid process
- 3 An anterior artery penetrating the base of the odontoid process. Note the rich anastomosing network within the odontoid process and the anastomosing arteries between the apical and basal arteries



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There were arteries running along with the accessory and apical ligaments penetrating into the odontoid process. No arteries could be seen to run into the bone from the interior of these ligaments. Vessels from the apical arcade ran along the alar ligament without penetrating the odontoid bone.

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REFERENCES

- Ames E W & Anderson F W (1956) Fracture of the odontoid process. *Arch Surg* 72 377-383.
- Anderson L D & d'Alonzo R T (1974) Fracture of the odontoid process of the axis. *J Bone Jt Surg* 56 A 1663-1674.
- Bailey R W (1974) *The cervical spine*. Febiger Philadelphia.
- Blockley N J & Purser D W (1956) Fracture of the odontoid process of the axis. *J Bone Jt Surg* 38 B 794-817.
- Böhler J (1963) Fractures of the odontoid process. *Trauma* 5 386-391.
- Crav's Anatomy. Ed Davis D V (1962) p 770. Longmans Green and Co Ltd London.
- Moseley F H & Goldie I (1963) The arterial pattern of the rotator cuff of the shoulder. *J Bone Jt Surg* 45-B 780-789.
- Mulfinger G L & Trueta J (1970) The blood supply of the talus. *J Bone Jt Surg* 52 B 160-167.
- Nacherson A (1960) Fracture of the odontoid process of the axis. *Acta orthop scand* 29 183-217.
- Peterson L, Goldie I & Lindell B (1974) The arterial supply of the talus. *Acta orthop scand* 43 260-270.
- Schatzker J, Norabek C H & Waddell J P (1971) Fracture of the dens (odontoid process). An analysis of thirty seven cases. *J Bone Jt Surg* 53 B 397-405.
- Schatzker J, Norabek C H & Waddell J P (1974) Non union of the odontoid process. *Clin Orthop* 108 127-137.
- Schäff D C & Pöschel W V (1973) The arterial supply of the odontoid process. *J Bone Jt Surg* 55-A 1450-1456.
- Schmöckel C (1971) *The human spine in health and disease*. Ed Junghans H. 2nd Amer edit. ed Basermann F F. Grune & Stratton, New York and London.
- Spalteholz K V (1914) *Leber das Durchsichtige Präparat von menschlichen und tierischen Präparaten*. zweite Auflage. S. Hirzel Leipzig.

RESULTS OF OPERATIVE TREATMENT OF LUMBAR DISC HERNIATION

A Survey of 886 Patients

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Over a period of 6 years (1960-65), 886 patients were operated on for herniated lumbar disc. In 1971, 695 of these patients (78.5 per cent) answered a questionnaire. The material was analysed with the aid of a computer. Persons in the age groups 30-39 (38 per cent) and 40-49 (34 per cent) were most prone to develop sciatica. At operation the distribution of positive findings was found to be 5.7 per cent at level L3-4, 58.3 per cent at L4-5 and 36 per cent at L5-S1. Myelography with a water soluble medium was performed preoperatively in all cases and gave a correct diagnosis of level in 90.2 per cent. The late results were good in 56 per cent of patients and 63 per cent returned to their former occupation.

Key words: lumbar disc herniation, operative results, sciatica, social factors.

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The initial enthusiasm regarding operation for lumbar disc herniation has in recent years been modified by reports of disappointing late results (Falconer et al 1948, Burns & Young 1951, Spurling & Grantham 1949, Kallio & Torma 1965, Karaharju et al 1974). Also there have been reports of good results after conservative treatment of sciatica (Hakelius 1970).

The purpose of this paper is to report an investigation, based on a questionnaire, of the primary and late results of patients operated on for disc herniation, during the period 1960-1965, at the Orthopaedic Hospital of the Invalid Foundation.

MATERIAL

From 1960 to 1965 a total of 886 patients were operated on for sciatica. In 1971 a questionnaire was sent to them. Answers came from 695 patients (78.5 per cent). The data obtained were analysed in a computer.

The operations were performed under general anaesthesia with the patients in a prone position. Exploration was carried out unilaterally with partial removal of laminar bone above and sometimes below the selected level. Hemilaminectomy and facetectomy were seldom necessary. All degenerated disc tissue was removed from the intervertebral space. A posterior fusion was performed simultaneously in 25 patients (2.9 per cent). The sex and age of the patients is shown in Table 1. Sixty-six per cent were males and 34 per cent females. Thirty-eight per cent of the patients belonged to the age group 30-39 years and 34 per cent to the age group 40-49.

Table 1 Sex distribution and number of patients in the various age groups

Age	Males	Females	All	%
10-19	3	1	4	0.4
20-29	50	24	74	8.1
30-39	212	121	333	38
40-49	194	111	305	34
50	134	46	170	20.5
	583 (66%)	303 (34%)	886	100

Table 2 Nature of work before operation

Heavy manual	239 (33%)
Manual	243 (27%)
Light	354 (40%)
Total	886 (100%)

Forty per cent were engaged in light work, 27 per cent in manual work and 33 per cent in heavy manual work (Table 2).

The preoperative duration of sciatica was 1-3 months in 42 per cent, 4-12 months in 44 per cent and more than 1 year in 14 per cent of the patients. Sixty-eight per cent had a history of back pain of more than 1 years duration. The radiating pain was left sided in 51 per cent, right sided in 40 per cent and bilateral in 9 per cent of cases. The Lasègue sign was positive in 81 per cent of the patients. There were eight patients (0.9 per cent) with a cauda equina syndrome. A total of 192 (14 per cent) had previously been operated on and had a second exploration because of recurrence of sciatica. In 35 patients two levels were explored and in 12 patients three levels.

A preoperative myelography with water soluble contrast medium (Contrast U) was performed in all cases (Table 3). The myelography was positive in 836 cases. Of these the operative finding was also positive in 693 cases (83 per cent) and negative in 51 cases (6 per cent). In

92 cases (11 per cent) the operative finding was marked as "adhesion". Out of the 50 casts with negative myelography findings the operative finding was also negative in 14 cases (28 per cent). Thus the myelographic and operative findings agreed with each other, if the cases recorded as "adhesion" are considered as positive findings, in 799 cases or 90 per cent. Of the 86 patients with a weakness of the extensor hallucis longus muscle the disc herniation was located at the level L4-5 in 68 cases, at L5-S1 in 12 and at L3-4 in 6 cases. Out of 200 patients with a weakened ankle jerk the herniation was located at the level L5-S1 in 143 patients and at L4-5 in 56 patients. The rate of negative exploration was 7.0 per cent (65/886). In 92 cases (11 per cent) the positive finding consisted of adhesions to the nerve root.

The distribution of positive operative findings was as follows: L3-4 level 5.7 per cent, L4-5 58.3 per cent and L5-S1 36 per cent.

Patients were allowed to walk about the day after operation. Physiotherapy was commenced if the patient's back was stiff 4-6 weeks after operation.

Complications

Two patients died of embolism of the lung 1 week after operation. The mortality rate was 0.2 per cent. Superficial wound infection occurred in 17 patients (1.9 per cent). Postoperative diverticula occurred in four patients (0.4 per cent). These healed with antibiotic treatment in 3-4 months.

RESULTS

Primary results

Of the 656 patients who answered this question 320 (49 per cent) returned to work within 4 months. Ninety-seven patients (15 per cent) were unfit to work for more than 6 months. If the period of inability to work had lasted for a long

Table 3 Myelographic and operative findings

Myelographic finding	Total	Operative finding		
		Positive	Negative	Adhesion
Positive	836 (100%)	693 (83%)	51 (6%)	92 (11%)
Negative	56 (100%)	31 (55%)	14 (25%)	5 (9%)
Total	886 (100%)	724 (82%)	65 (7%)	97 (11%)

Table 4 Primary results comparison of periods of inability to work before and after operation

Period of incapacity before operation (months)	Total	Period of incapacity after operation (months)			
		Less than 2	2-4	4-6	Over 6
0-3	282 (100%)	155 (55%)	87 (31%)	23 (8%)	17 (6%)
3-6	150 (100%)	73 (49%)	41 (27%)	10 (7%)	27 (18%)
6-12	135 (100%)	64 (48%)	37 (27%)	11 (8%)	23 (17%)
Over 1 year	89 (100%)	25 (31%)	18 (20%)	12 (14%)	31 (35%)
Total	656 (100%)	320 (49%)	183 (28%)	56 (9%)	97 (15%)

Table 5 Primary results Period of inability to work after operation divided according to nature of work

Work before operation	Total	Returned to work in			
		Less than 2 months	2-4 months	4-6 months	Over 6 months
Heavy manual	258 (100%)	83 (32%)	82 (32%)	32 (12%)	61 (24%)
Manual	268 (100%)	137 (51%)	78 (29%)	21 (8%)	32 (12%)
Light	130 (100%)	100 (77%)	23 (18%)	3 (2%)	4 (3%)
Total	656 (100%)	320 (49%)	183 (28%)	56 (9%)	97 (15%)

Table 6 Late results in terms of the patients' condition at follow up

Age	Total	Condition of patient at follow up		
		Cured	Unchanged	Worse
Under 40 years	306 (100%)	189 (62%)	90 (29%)	27 (9%)
Over 40 years	314 (100%)	155 (49%)	114 (37%)	25 (8%)
Total	620 (100%)	344 (56%)	224 (36%)	52 (8%)

time before operation convalescence also took a long time (Table 4). The nature of the work also influenced the period of convalescence (Table 5).

Good or satisfactory results were obtained in 70 per cent of cases, fair results in 14 per cent and poor in 16 per cent.

Late results

Some patients did not answer all the questions and therefore the patient groups differ in number of cases.

The follow up time was 6-11 years. At follow up 344 out of 620 patients (56 per cent) stated that they had little or no pain (Table 6). In 224 patients (36 per cent) the pain was the same as before operation and in 52 (8 per cent) it had become worse. As regards fitness for work at follow up 284 out of 620 patients (46 per cent) stated that they were fully capable of working, and 274 patients (44 per cent) were in their opinion only partially capable. Namely four patients

Table II Late results Nature of work at follow-up

Work before operation	Total	Previous	Work at follow up			
			Lighter	Heavier	Not working	On pension
Heavy manual	236 (100 %)	128 (55 %)	33 (14 %)	—	15 (6 %)	60 (25 %)
Manual	249 (100 %)	158 (64 %)	11 (7 %)	6 (2 %)	24 (10 %)	43 (17 %)
Lght	124 (100 %)	108 (87 %)	—	3 (2 %)	6 (5 %)	7 (6 %)
Total	636 (100 %)	394 (66 %)	51 (8 %)	9 (2 %)	45 (7 %)	110 (17 %)

(14 per cent) stated that they were unfit for work

Out of 636 patients 394 (66 per cent) had returned to their former employment (Table 7) 51 patients (8 per cent) had changed to a lighter job and 9 patients (2 per cent) to a heavier job 155 patients (24 per cent) stated that they were unfit for work 110 of them (17 per cent) were receiving a pension At the time of the follow up 47 patients were over the age of 63

The results of 43 fusion operations 29 in connection with the disc prolapse removal and 18 at a later stage were satisfactory in half the cases and poor in the other half

DISCUSSION

Low back pain and sciatica are among the commonest causes of inability to work Conservative treatment should always be tried first and patients should be carefully selected for operation

According to this investigation the following criteria indicated a good result after operative treatment of a prolapsed disc

Medical factors No previous back operations Painful preoperative signs of a herniated disc A short period of sciatica before operation

Social factors Patient not in heavy work or able to change to lighter work if necessary Preoperative period of unem-

ployment as short as possible Education more than elementary school The younger the patient the better his prognosis

In this series 93 per cent were doing heavy manual work and 10 per cent non manual work This means that a herniated disc can occur in any category of work It is clear however that after operation those doing heavy manual work more often have back pain and recurring sciatica In younger individuals training for a new lighter occupation is often advisable

In this series the distribution as regards age and sex of the patients was approximately the same as in other published studies collected by Sprangfort (1972)

Seventy two per cent of the patients belonged to the age group 30-49 The distribution of the level of a positive finding during operation was as follows 57 per cent L 3-4 58.3 per cent L 4-5 and 30 per cent L 5 S1 The rate of herniation at the level L4 5 was somewhat higher in this series than in other publications

It is difficult to decide the level of herniation on the basis of clinical findings Myelography using a water soluble contrast medium (Contrast U) gave a correct diagnosis of level in 90.2 per cent of patients A negative myelogram sometimes is taken as a contraindication to operation The clinical signs are decisive however a herniation in a large L5 S1 space for instance will not always be

visualized during myelography. The new myelography technique with Dimer-X makes exposure in a standing position possible, which makes the investigation even more reliable. In our hospital myelography always precedes an operation. In this series there was a tendency for disc herniation to be located at a higher level with increasing age, which agrees with the observations of Spangfort (1972).

Results indicate that an operation should be considered if a period of 4-6 weeks of conservative treatment gives no relief from pain. If the patient has severe pain, or there are clear signs of root compression and the myelogram is positive, an operation is indicated even sooner. Under these circumstances if the operative finding is positive, the result of operation is generally good. It may seem, however, that the condition of the patient's back 5-11 years after operation is not as satisfactory as the primary results indicated. If the patient is near retirement, prolonged conservative treatment is advisable. The results of reoperation for herniated disc on the same side and level as the primary operation seem not to be very satisfactory. A simultaneous fusion may be indicated by the second exploration. The results of this procedure, however, gave a satis-

factory result in only about half the patients. The results after a third intervention are often poor.

The late results in this series are comparable with earlier published results. 56 per cent of the patients stated that they had little or no pain, and 63 per cent had returned to their former employment.

REFERENCES

- Burns, H. H. & Young, R. H. (1951) Results of surgery in sciatica and low back pain. *Lancet* **i** 245-249.
- Falconer, M. A., McGeorge, M. & Begg, A. C. (1948) Surgery of lumbar intervertebral disc protrusion. *Brit J Surg* **35** 225-249.
- Hakellus, A. (1970) Prognosis in sciatica. A clinical follow up of surgical and non surgical treatment. *Acta orthop scand* Suppl 129.
- Kallio, I. & Torma, T. (1965) Late follow up of lumbar disc surgery without fusion. *J int Coll Surg* **44** 191-196.
- Karaharju, I., O. Alho, A. & Laasonen, T. (1974) Herniated lumbar disc: postoperative condition and correlation with preoperative and postoperative findings. *Ann Chir Gynaec Fenn* **63** 53-56.
- Spangfort, V. (1972) Lumbar disc herniation: A computer aided analysis of 2504 operations. *Acta orthop scand* Suppl 142.
- Spurling, R. G. & Grantham, F. G. (1949) The end results for ruptured lumbar intervertebral disc. *J Neurosurg* **11** 57-64.
- Waris, W. (1948) Lumbar disc herniation. *Acta orthop scand*, Suppl 10.

DOUBLE BLIND EVALUATION OF EXTRADURAL METHYL PREDNISOLONE FOR HERNIATED LUMBAR DISCS

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A double blind study was carried out in 51 patients suffering from lumbar root compression syndrome of 12 days to 36 weeks duration. All patients had signs, symptoms and radiological abnormalities related to a herniated lumbar disc. Each patient received an extradural injection of either 2 ml (80 mg) methyl prednisolone or 2 ml normal saline solution. Neurological examination and interview of the patients with the aid of a questionnaire before and after extradural injection failed to demonstrate any statistically significant difference in outcome between the two groups. At follow up 14 ± 6 months after extradural injection 53.3 per cent of the patients in the control group and 51.9 per cent of the patients in the treatment group had undergone surgical treatment with laminectomy. Our results indicate that a single extradural injection of methyl prednisolone (80 mg) is no more effective than a placebo injection in relieving chronic symptoms due to myelographically demonstrable lumbar disc herniation.

Key words: sciatica, intervertebral disc displacement, extradural injections, methyl prednisolone.

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For more than 20 years water-soluble corticosteroid drugs have been used in the treatment of sciatica. Various administrative techniques have been employed. Extradural injection at the affected lumbar level (Barry & Hume Kendall 1962), or at the sacro-coccygeal level via the sacral hiatus (Lundblom & Salenius 1964) and via dorsal sacral foramina (Renier 1959), local intrathecal injection (Sehgal & Gardner 1960) and systemic application by the intramuscular route (Green 1975), have all been advocated. Corticosteroid infiltration of the extradural space at the affected spinal level now appears to be the most

popular technique. If effective it constitutes a major advance in the non-operative management of the lumbar root compression syndrome. It is rapid, can be performed on an out-patient basis and appears to be safe (Jurmand 1973), although warnings have been given about the dangers of intraspinal injections without proper diagnosis (Shealy 1966). Many papers appear to prove the effectiveness of extradural steroid injections but there is a scarcity of controlled studies which take account of the variable and episodic nature of the pain characterizing the natural history of the lumbar root compression syndrome.

Table 1 Comparability of groups before injection. Clinical data of 51 patients with herniated lumbar disc

	Placebo	Methyl prednisolone
Total treated	24	27
Average age in years (range)	46.5 (27-67)	43.8 (26-59)
Sex		
Males	13	13
Females	11	14
Duration of main complaint (present attack)		
Average	10.8 weeks	11.5 weeks
Range	17 days-36 weeks	12 days-36 weeks
Vertebral levels of disc herniation		
L ₃ -L ₄	2	
L ₄ -L ₅	11	15
L ₅ -S ₁	11	12
Neurological deficit	24	27
Sciatic scoliosis and/or lumbar deviation	15	16
Positive Lasague's sign	20	22
Abnormal ankle jerk	15	12
Non-progressive lower extremity weakness	9	8
Radicular sensory deficit	10	10
Pain	24	27
Low back pain	8	9
Radiating pain	24	27
Impulse pain	14	20
Pain interfering with sleep	13	13
Necessity for analgesics	19	20
Records obtained from physiotherapist	14	20

(Pearce & Moll 1967) The aim of the present study therefore is to evaluate objectively methyl prednisolone, 80 mg, applied extradurally at the fourth lumbar, fifth lumbar or first sacral nerve root level in the treatment of the lumbar root compression syndrome

MATERIAL

The patients included in this study were selected from a consecutive series of more than 200 patients admitted to the Department of Neurology, Ullevål Hospital between May 1974 and April 1975, for treatment of unilateral sciatica.

The criteria for admission to this trial were the presence of (1) radiating pain in the distribution of the sciatic or femoral nerves, (2) a neurological deficit that correlated with a compression of the fourth or fifth lumbar or first sacral nerve root and (3) myelographic findings

at the appropriate level and side. Lumbar myelography was performed with metrizamide (Amipaque®). Radiologically diagnostic features were indentation of the dural sac and/or increased width of the root and shortening of the root sleeve.

Grounds for exclusion were acute severe motor paresis, evidence of compression of the cauda equina, intolerable pain, previous surgery to the lumbar spine, coincident medical conditions known to be contraindications to corticosteroid therapy and any doubt about the myelographic findings.

51 patients satisfied the criteria and consented to participate in the trial.

METHODS

The selected patients were randomly divided into two comparable groups (Table 1) by one of the authors (B.J.). The control group received a lumbar extradural injection of 2 ml of normal

saline and the treated group received an injection of 80 mg (2 ml) methyl prednisolone acetate (Depo Medrol®). All injections were performed by BJ using the direct approach through the interspinous ligament at the level of the disc lesion as described by Barry & Home Kendall (1962). The patients were placed on the affected side with hips and spine fully flexed. The extradural space was identified by the loss of resistance test" of Dogliotti (1933), and after the injection the patients were left on the same side for a few minutes to allow accumulation of the steroid at the required level and side.

All patients were restricted to bed for the first 7 days of hospitalization but from the eighth day were allowed to walk about freely. Physiotherapy mainly consisting of instruction and isometric training of the appropriate muscle groups was identical for all. The duration of stay at the department of neurology was 14 ± 4 days. Those patients who did not improve sufficiently were then transferred to the physiotherapy department or to the neurosurgery department if a complete evaluation indicated the need for laminectomy.

All patients were examined by the same neurologist (W.S.) 12 ± 10 hours before and 48 ± 24 hours after the injection. Neither patient nor examiner knew to which group the patient belonged. The following variable factors were recorded:

1) Mobility and deformity of the lumbar spine

The spinal process of L_4 and S_1 were marked on the skin. The patient stood with his back to the examiner with equal weight on both feet and a plumb line was suspended in such a manner that it covered the spinal process of S_1 at all times during the examination. Any sciotic scoliosis or lumbar deviation was recorded and if it disappeared after . . .

spinal process of L_4 was recorded (Figure 1). Thus a reproducible expression of the mobility in the frontal plane was obtained. The examiner constantly checked with his hands that the hip area did not move. The mobility in the sagittal plane was recorded as the difference in the distance between S_1 and L_4 in the neutral position and maximal forward and backward flexion respectively. An increase in mobility of 2 cm or more in either plane after injection was categorized as improvement.

2) Lasqueg's test

This was performed with the patient lying on his back keeping the knee straight the leg was

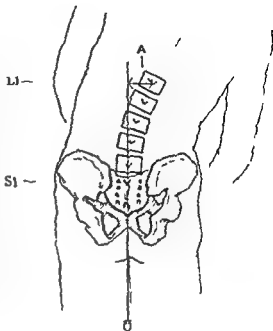


Figure 1 Measurement of mobility in the frontal plane of the lumbar spine. The patient performs a maximal lateral flexion to both sides. The distance A between the plumb line through S_1 and the spinous process L_4 is measured in cm (From Weber 1973).

slowly raised until the patient experienced radiating pain in the distribution of the sciatic nerve. A "positive Lasqueg's sign" was recorded when the test provoked radiating pain before 50° elevation was accomplished. The recording of the angle of elevation was made with a goniometer. If after injection the angle had improved by 20° or more this was recorded as increased sciatic nerve stretch tolerance.

3) Neurological deficit

a) Anterior and posterior drawer tests. The knee joint was examined with the patient lying on his back and the seventh strike against the Achilles tendon. Deviation of the movement of the foot on the unaffected leg was used as a control.

b) Motor function. This was examined in all patients by the conventional manual technique. The strength of the muscles with the following functions was measured during maximum isometric contraction: dorsal extension of the big toe, the four lateral toes and the entire foot; eversion of the foot; abduction and extension of the leg; and flexion of the foot and the knee.

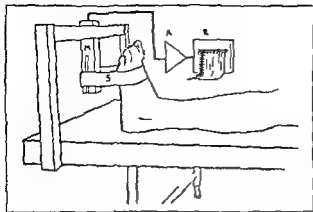


Figure 2 Measurement of strength in the muscle groups which cause dorsal flexion of the foot (from Weber 1975)

The maximum muscle strength here is defined as the maximum force which the muscle can develop and maintain for a brief period of time (1-2 seconds). In 17 patients with a detectable paresis, the isometric strength in the affected muscle groups was recorded mechanically as shown in Figure 2. The patient lay on a bench. With the aid of a non-stretchable strap, the foot was fixed to a measurement beam with built-in strain gauges. The electrical signals were transferred to a direct recorder which showed the deflections on squared paper. The mean value of two readings was recorded but if the difference between these exceeded 5 per cent of the deflection a third measurement was made. In this way one always obtained two recordings which satisfied the requirements. Corresponding muscle groups were examined alternately in the affected and the unaffected leg with exactly the same starting position and necessary support. The difference in the measured strength in the two legs provided an expression of the degree of the paresis and corresponded well with the clinical evaluation.

c) *Sensory function* The patient's reaction to pin pricking was examined in both legs. In 20 instances a radicular sensory deficit was detected and the localization and extent of this were recorded on a sensibility scheme.

4) Pain

For the patient with sciatica, pain is the dominating and most disabling symptom. With the aid of a questionnaire the subjective pain was recorded before and after injection. The following types of pain were defined and assessed:

a) low back pain, which was a prominent feature in only 17 of the patients. If it disappeared after injection, this was recorded as improvement.

b) radiating pain in the distribution of either the sciatic or femoral nerve was present in all patients. If it disappeared or did not extend as far after injection, this was recorded as improvement.

c) impulse pain, i.e., provocation or worsening of radiating pain by coughing or sneezing is thought to be a sign of spinal nerve root irritation and was present in 34 patients of our series. If this sign disappeared after injection this was recorded as improvement.

d) pain interfering with sleep, waking the patient at night or completely inhibiting normal sleep was reported in 26 cases. Improvement was recorded if after injection the subjects no longer awakened because of pain.

5) Analgesic consumption

The patients were given an analgesic tablet on request only. Two different compounds were used, but each patient only received one of these. If after injection the patient no longer requested any analgesic, this was recorded as an improvement.

6) Statement by the physiotherapist

The patient's physiotherapist recorded his impression of the condition of the patient on the basis of clinical judgement of the patient's ability to perform physical activities before and after injection. The physiotherapist did not know which type of injection had been given. Records were only available for 35 of the patients.

7) The patient's own assessment

At the second examination the patient was asked if he subjectively felt an improvement, had experienced no change or had deteriorated after the extradural injection.

RESULTS

Early results

Table 2 presents the results, indicating a general improvement in both the treated and the control group. The difference in results between the two groups is statistically not significant.

Follow-up study

All patients included in this study were reviewed in December 1975. The follow-up period ranged from 8 months for

Table 2 Early results

	Placebo (%) *	Methyl prednisolone (%) *	P **
Improvement of sciatic scoliosis and/or lumbar deviation	33.3	12.5	0.34
Increased mobility in lumbar spine			
Sagittal plane	8.3	25.9	0.20
Frontal plane	50.0	44.4	0.92
Increased sciatic nerve stretch tolerance	25.0	36.4	0.65
Improvement of abnormal ankle jerk	0.0	0.0	
Improvement of lower extremity weakness	0.0	25.0	0.40
Improvement of radicular sensory deficit	0.0	0.0	
Relief of low back pain	25.0	33.3	0.88
Relief of radiating pain	12.5	25.9	0.37
Relief of impulse pain	7.1	25.0	0.38
Relief of pain interfering with sleep	23.1	53.8	0.24
Discontinuance of analgesic consumption	15.8	40.0	0.19
Improvement stated by physiotherapist	42.8	70.0	0.22
Improvement felt subjectively by the patient	41.7	66.7	0.13

* Refers to the number of affected patients who improved, not the degree of improvement. Compare with basic data in Table 1.

** Differences between groups have been tested by ordinary chi square statistical methods with one degree of freedom and with Yates correction, regarding *P* values less than 0.05 as significant.

those admitted in April 1975 to nearly 20 months for those admitted in May 1974. The patient records were reviewed to ascertain whether laminectomy had been necessary since injection. Where this information could not be obtained from the record, the patient was contacted by letter or telephone. Review of the operation records from the department of neurosurgery showed that in all the cases operated upon, i.e., 14 patients in each group, a disc prolapse was found at the level and side indicated by myelography.

Complications

Apart from a few patients who felt increased pain of sciatic distribution shortly after the extradural injection, there were no complications or side effects attributable to the injection.

DISCUSSION

In our study there was no statistically significant difference in the outcome between the treated and the control group. It follows that a single dose of methyl prednisolone, 80 mg injected extradurally was no more effective than the placebo in relieving chronic symptoms due to lumbar disc herniation demonstrable by myelography.

Our conclusion is derived from a small number of patients and contradicts the wider based experience of many different researchers. However, of the previous trials only Dilke et al (1973) have reported a carefully controlled double blind study of extradural steroid medication. In a series of 100 consecutive patients with a clinical diagnosis of lumbar root compression by a herniated lumbar disc they observed significant alleviation of the symptoms after injection of methyl prednisolone, 80 mg. The apparent disparity in results between their study and

our own may be related to a difference in selection of material since Dilke et al did not consider myelography findings as a criterion, whereas all the patients in our study had a demonstrable disc herniation. Harley (1967) demonstrated that most of the patients who benefit from extradural steroid infiltration have no myelographic abnormality, and Colonna & Friedenherg (1949) showed that the prognosis of non-operative treatment is poorer when the extruded mass of the disc reaches a stage where it can be visualized by myelography.

Our results reflect the findings at 48 ± 24 hours after treatment. Burn & Langdon (1974) found a temporary relief of symptoms in 37 per cent of their patients treated with extradural steroid injection and manipulation under anaesthesia. The period of relief of symptoms varied from only a few days to several months. It may be therefore that further follow-up of our own patients would have yielded even poorer results.

Our placebo injection appeared to be strikingly effective. It is unreasonable, however, to suspect any therapeutic action from extradural injection of 2 ml normal saline. Certainly Evans (1930) found that extradural injection of 30 ml of normal saline relieves sciatic pain, but this is fifteen times the amount used in our study. More likely the general improvement of our patients in both groups is at least in part due to the strict bed rest which was instituted directly after admission.

In this study myelography was performed with metrizamide (Amipaque®), a water-soluble contrast which has been shown to have markedly reduced irritative effects compared with other water-soluble contrast media (Skalpe et al 1973). The use of metrizamide is therefore unlikely to have had any direct effect in itself on the patients' symptoms or signs.

In assessing the significance of our

results, it should also be taken into account that only a single dose of methyl prednisolone, 80 mg, was given and only patients with long-standing symptoms of lumbar root compression, nearly 3 months' duration on average, were included in our study. According to Solheim (1960) and Jurmand (1973) acute cases of sciatica respond better to extradural steroid infiltration than do the subacute and chronic cases. Dilke et al (1973) claim that a second injection of methyl prednisolone given a few days after the first may be successful when there has been incomplete or even no response to the first, whereas a third injection is rarely helpful. Burn & Langdon (1974) showed that the duration of action of methyl prednisolone when injected into the extradural space was about 2 weeks. Hence another injection after a few days means accumulation of the active substance. We found it difficult, however, to investigate with double blind methods the possible effect of repeated injections. Further investigations are required to assess objectively the value of higher steroid dosage and the effectiveness of extradural steroid medication in acute cases of sciatica with and without myelography findings.

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REFERENCES

- Barry P & Hume Kendall P (1962) Corticosteroid infiltration of the extradural space. *Ann. phys. Med.* **11**, 267-273.
- Burn J & Langdon L (1974) Duration of action of epidural methyl prednisolone. *Amer. J. phys. Med.* **53**, 29-34.

- Colonna P C & Friedenberq Z B (1949) The disc syndrome Results of the conservative care of patients with positive myelograms *J Bone Jt Surg* 31 A 614-618
- Dale T F W., Burry H C. & Grahame H (1973) Extradural corticosteroid injection in management of lumbar nerve root compression. *Br J med J* ■ 633-637
- Dogiel A M (1933) cited by Barry & Hume Kendall (1967)
- nos W (1930) Intraspinal epidural injection in the treatment of sciatica *Lancet* ■ 1223-1229
- Green L A (1975) Dexamethasone in the management of symptoms due to herniated lumbar disc *J Neurol Neurosurg Psychiat* 38 1211-1217
- Harley C. (1987) Extradural corticosteroid infiltration A follow up study of 50 cases *Ann Phys Med* 9 ■ 78
- Jurmand S H (1973) Les injections périurales de corticoïdes dans le traitement des lombalgies et des sciatiques d'origine discale *Rev Rhum* 40 461-464
- Lindholm R & Salenius P (1964) Caudal epidural administration of anaesthetics and corticoids in the treatment of low back pain *Acta orthop scand* 35 144-156
- Pearce J & Moll J M H (1967) Conservative treatment and natural history of acute lumbar disc lesions *J Neurol Neurosurg Psychiat* 30 13-17
- Renier J C. (1959) L'infiltation epidurale par le premier trou sacré postérieur *Rev Rhum* 26 526-532
- Shealy C. V. (1966) Dangers of spinal injections without proper diagnosis *J Amer med Ass* 197 156-158
- Sehgal A H & Gardner W J (1960) Corticosteroids administered intradurally for relief of sciatica *Cleveland Clin Quart* 27 198-201
- Skalpe I O, Torbergsen T., Amundsen P & Presthus J (1973) Lumbar myelography with metrizamide *Acta radiol (Stockh)* Suppl 333 367-379
- Solheim S B (1960) Epidural hydrocortison injeksjon ved lumbago ischias (in Norwegian) *T norske Lægeforen* 80 753-758
- Weber H (1973) Traction therapy in sciatica due to disc prolapse *J Oslo City Hosp* 23 167-176
- Weber H (1975) The effect of delayed disc surgery on muscular paresis *Acta orthop scand* 46 631-642

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REFERENCES

- Barry P. & Hume Kendall P. (1962) Corticosteroid infiltration of the extradural space. *Ann. phys. Med.* 6, 267-273.
- Burn J. & Langdon I. (1974) Duration of action of epidural methyl prednisolone. *Amer. J. phys. Med.* 53, 29-34.

Table 1 Incidence of neonatal hip instability

Author and date of study	Comments	Incidence (Per mille)
<i>Sweden</i>		
Palmén 1961	Own material	5.7
Palmén 1961	Obstetric clinics (1953-1960)	2.2
Palmén 1961	Obstetric clinics (1953-1960) with provoked instability test	5-6
Palmén 1961	Clinics in Gothenburg and Malmö	2.0
Emoëus 1966	63/16 638	3.8
James & Hierton 1968	All cases admitted for orthopaedic consultation	20.0
Emoëus & Undeland 1970		4.5
von Rosen 1970	1956	1.3
	1965	12.0
	Average	4.7
Hirsch & Scheffer 1970	1961	13.0
	1962	12.9
Palmén & von Rosen 1975	For the whole country (1963)	5.6
Fredensborg 1975		9.3
<i>Elsewhere</i>		
Barlow 1962		14.9
Finlay et al 1967		5.0
Williamson 1972	192/29 000	6.6
Mackenzie 1972	1969-1970	21.8
Bjerkreim 1974		8.0
Artz et al 1975		13.3
Nielsen 1975		0.74

sented, especially of the pioneering work of Palmén and von Rosen. The incidence of neonatal hip instability has been calculated. Table 1 gives some of these figures as well as the incidence in some other countries.

In the thesis presented by Fredensborg in Malmö (1975), it was stated that early diagnosis and treatment had been very successful during the period 1956-1972, only 0.07 per mille were diagnosed after the neonatal period (\approx first month of life). Other investigators have found, however, that early diagnosis and treatment has not considerably reduced the number of so called "missed" cases (Williamson 1972, Mackenzie 1972, Bjerkreim 1974, Nielsen 1975). Even in Sweden when one compares the last few years with the mid sixties (Palmén & von Rosen 1975, Palmén 1977, personal communication), there is a tendency for

more cases to be diagnosed during the age of 1-6 months.

In Uppsala early diagnosis and treatment started in the late fifties. It is now an established routine procedure, in principle the same as in other Swedish maternity wards with regular examinations by paediatric consultants. Nevertheless there are a few "missed" cases every year, which are picked up later in the Paediatric Health Care Centres. The following study has been undertaken with the purpose of elucidating and examining the effectiveness of our diagnostic and therapeutic routines.

MATERIAL AND METHODS

The material consists of all children who have been referred in the neonatal period (\approx first month of life) from the maternity ward to the orthopaedic department in the University Hospital of Uppsala with signs of hip instability.

NEONATAL HIP INSTABILITY

Incidence, Diagnosis and Treatment at the University Hospital, Uppsala, 1960-1964 and 1970-1974

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Neonatal hip instability, its incidence, diagnosis and treatment has been studied retrospectively for the periods 1960-1964 and 1970-1974. The respective populations for the two periods amounted to 13 065 and 16,274 children all born at the same hospital. During the first period 191 children (14 per mille) were referred from the maternity ward to the orthopaedic department with suspected hip instability, 109 (83 per mille) children were considered by the orthopaedic consultant to have unstable hips. During the second period the corresponding figures were 503 (31 per mille) referred to the orthopaedic department and 189 verified as unstable (11.6 per mille). During the first period 177 children were treated with Frejka pillows for about 3 months, only 14 being left untreated. In seven children the initial treatment was complicated with a plaster cast. The results were uniformly good. During the second period 193 children were treated with a von Rosen splint for 6 weeks followed by Frejka pillows for another 6 weeks (seven complicated treatment with plaster). In 143 cases Frejka pillows were the sole treatment and 161 had no treatment at all. There was one primary plaster. The treatment resulted in normal hips in all but one girl. In the non-treated group three subluxations were verified after the neonatal period. There were seven 'missed' cases (diagnosed after the first month of life) in the first population (0.5 per mille), 15 in the second (0.9 per mille). This difference is not statistically significant. The calculated incidence of dislocations if no treatment had been instituted in the neonatal period is 1.5 per mille in the first population and 2.3 per mille in the second. The difference is not statistically significant.

Key words: CDH, hip instability, neonatal incidence

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In 1956, Severin calculated the incidence of children with congenital dislocation of the hip in Sweden. The children with this diagnosis were traced via the orthopaedic departments throughout the country. They were generally more than 1-year-old when diagnosed. No treatment had been given during the neonatal

period at that time (1936-1945). Severin found that 0.9 per mille of children born alive had CDH. He remarked that this figure was a minimal one.

During the past 25 years, early treatment of neonatally unstable hips has become standard practice in Sweden. Many large materials have been pre-

Table 3 Number of children A With verified instability at the orthopaedic examination during the neonatal period B With stable hips at the orthopaedic examination during the neonatal period C Referred after the neonatal period with unstable hips

Year	No born alive	A	B	C
1960	2 295	1	—	1
1961	2 193	7	1	3
1962	2 468	26	15	1
1963	2 803	40	28	1
1964	3 306	35	38	1
	13 065	109 (8.3 per mille)	82 (6.3 per mille)	7 (0.54 per mille)
1970	3 096	38	79	1
1971	3 383	53	46	5
1972	3 296	52	78	4
1973	3 215	24	56	3
1974	3 304	22	55	2
	16 274	189 (11.6 per mille)	314 (19.2 per mille)	15 (0.92 per mille)

Table 4 Various forms of treatment in children referred for neonatal hip instability and number of children treated

Year	von Rosen splint (+ Frejka pillow)	Only Frejka pillow	Plaster	No treatment	Total
1960	—	1	—	—	1
1961	—	7	—	1	8
1962	—	32	(4) *	9	41
1963	—	67	(3) *	1	68
1964	—	20	—	3	73
		127	(7) *	14	191
1970	44	55	(1)	15	114
1971	54	23	(3) *	27	99
1972	50	33	1 (+ 1) *	46	130
1973	33	20	—	35	80
1974	22	17	—	38	77
	195	143	1 (+ 7) *	161 **	500

The figures in parentheses indicate cases where treatment started with Frejka pillow or von Rosen splint but later changed to plaster. These are included in the group according to initial treatment.

In this group three children were treated after the neonatal period.

been treated with plaster where slight dysplastic changes were still visible at 2.5 years of age.

During the years 1970–1974 a von Rosen splint for 4–6 weeks, followed by a Frejka pillow for another 6–8)

during the years 1960-1964 and 1970-1974. These children have been examined by a consultant paediatrician once during their first 24 hours and again before leaving the hospital at about 1 week of age. The orthopaedic examination was done 1-4 days after the paediatric examination in the majority of the cases. When indicated treatment was started immediately after the orthopaedic examination. Retrospectively, the material has been classified according to diagnosis, type and results of treatment. The 5 year incidence of neonatal instability has been calculated for the two periods. The incidence of late (= after the first month of life) diagnosis has been estimated separately.

RESULTS

Diagnosis

In Table 2 the total number of infants born alive each year and the total number referred for orthopaedic examination during the same period are presented. There is a rapid increase during the early years of the sixties. During the later period the total number of patients referred has more than doubled compared with the first.

At the orthopaedic examination, the paediatric diagnosis of hip instability has been verified in a number of cases. Verified instability means a positive Ortolani sign and/or a positive provoked instability test, or a totally dislocated hip (rare). Table 3 presents the number of children with verified hip instability (A) and the number where instability could not be verified (B). This table also presents the number of children referred after the neonatal period ("missed" cases) (C). None of these had been referred for orthopaedic examination during the period in the maternity ward. They were discovered at an age of 6 weeks to 20 months, being mainly referred from the paediatric Health Care Centres.

During the first period instability was verified in 109 newborn patients. The total population was 13,065, giving an incidence of $109/13,065 \approx 8.3$ per mille. The corresponding figure for the second

Table 2 Number of children referred from the maternity ward for orthopaedic examination

Year	No born alive	No referred from maternity ward	Per mille
1960	2295	1	0.4
1961	2193	8	3.6
1962	2468	41	16
1963	2803	68	24
1964	3306	73	22
	13,065	191	14.6
1970	3096	117	37
1971	3363	99	29
1972	3296	130	39
1973	3215	80	24
1974	3304	77	22
	16,274	503	30.9

period is $189/16,274 \approx 11.6$ per mille. There is a statistically significant difference between these two figures. The number of patients in group B shows an increase from $82/13,065 \approx 6.3$ per mille to $314/16,274 \approx 19.2$ per mille. In group C the small difference between the incidence in the first and the second period (0.54 versus 0.92 per mille) is not statistically significant.

Treatment

As can be seen from Table 4, during the period 1960-1964 the treatment always started with a Frejka pillow for about 3 months. Nearly every child referred to the department had this treatment even if the hips were considered stable at the orthopaedic examination. This simple treatment was in seven cases completed with plaster. The reason for the treatment with plaster was persisting instability after the Frejka treatment in two cases and persisting X-ray changes interpreted as "dysplasia" in five cases.

All hips, including those with plaster, remained stable after this treatment. X-ray examinations at 3 months and/or at 1 year or later displayed normal development, except in one case which had



Figure 2 Girl born 24 April 1973. Examinations in the maternity ward 25 April normal hips
 ■ April positive Ortolani bilaterally 30 April laxitas (?) Examinations by orthopaedic surgeon
 29 April 13 May 10 June normal hips 3 July restricted abduction left side 21 August same +
 leg shortening X ray Acetabular dysplasia + subluxation left side Arthrography Unstable caput
 femoris left side with cranial dislocation of the labrum (arrow)

and dysplasia (Figure 2). After treatment in plaster the hips became stable with normal X ray appearance.

DISCUSSION

Incidence

During the period 1960–1964 8.3 per mille of the newborns were verified as having unstable hips by the orthopaedic specialist compared with 11.6 per mille during the second period. This difference is statistically significant. There was at the same time no significant change in the number of cases diagnosed after the neonatal period (Table 3).

Bjerkreim (1974) calculated the incidence of neonatally diagnosed cases in south east Norway for the period 1965–1969 to be 8 per mille. Cases diagnosed later (> 1 month) amounted to 2 per mille, mostly subluxations and dysplasia. During the sixties he noticed an increasing number of neonatal as well as late cases when less serious cases were included. Palmén (1977, personal communication) has during more recent

years (1973–1975) found a large number of cases diagnosed in the age group 1–6 months in all of Sweden. Bjerkreim and Palmén feel that this increase is due to the increased activity at the Paediatric Health Care Centres, where much attention has been directed towards the problem of unstable hips in infants.

The experience of the Malmö region as presented by Fredensborg (1975) is quite contrary to this. There was an increase in the number of neonatal cases in Malmö in the middle of the sixties, but late cases were extremely rare (four in 16 years). The increase in neonatal cases is thought to be due to the fact that many different doctors were involved in the examination of the newborns (Fredensborg et al 1977).

It is generally assumed that the increase in the number of diagnosed cases is the result of intensified diagnostic work and thus not a true increase in hip instability. Of course one cannot exclude the possibility that some change in the environment can influence the occurrence of neonatal instability. The examination itself may be of some importance



Figure 1 Girl with very unstable hips bilaterally when newborn, even when fixed in a von Rosen splint. She was treated from the start in abduction plaster. Irregular ossification in the epiphysis and metaphysis was seen for the first time at 11 months (Figure 1 A). X-ray at 3 years (Figure 1 B).

weeks has been the normal treatment in newborn cases with verified instability. In six cases the splint was changed to plaster after a short time because of persistent instability at the check-ups. In one case sufficient stability could not be attained with a splint, and treatment with plaster was started at once. In another case treatment in an abduction splint was prolonged because the X-ray check-up at 4 months showed signs of dysplasia.

All cases treated with von Rosen-Frejka, with the exception of those mentioned above, were clinically normal within 12 weeks. A final clinical and X-ray examination was done at about 4 months.

The cases treated in plaster have stable hips except in one bilateral case, where

one hip remains unstable even after a series of operative procedures. The girl who was treated in plaster from the start is clinically normal but X-ray examination has shown some structural defects in the hip (avascular necrosis?) (Figure 1).

Children, where instability could not be verified, were either treated with Frejka pillows for about 6 weeks (161) or were not given any treatment (143). The examining orthopaedic surgeon selected the cases on an individual basis. The children treated with Frejka pillows have all responded satisfactorily. Three cases in the non-treated group presented later (6 weeks-4 months) with restricted abduction in the suspected hip. Arthrographies of the hips showed instability

ing the risk of missed cases and the simplicity of the treatment when started early this might have been justified. A certain degree of over treatment cannot be avoided if the diagnostic criteria cannot be improved.

REFERENCES

- Ariz T D, Lewin U B, Lim W G, Salvati E A & Wilson Jr P D (1975) Neonatal diagnosis treatment and related factors of congenital dislocation of the hip *Clin Orthop* 110 112-136
- Barlow T H (1962) Early diagnosis and treatment of congenital dislocation of the hip *J Bone Jt Surg* 44 B 292-301
- Bjerkreim I (1974) Congenital dislocation of the hip joint in Norway *Acta orthop scand Suppl* 157
- Emnéus H (1966) Some new aspects of the treatment of congenital dislocation of the hip (CDH) according to Palmén von Rosen *Acta orthop scand* 37 311-316
- Emnéus H & Ljödland K (1970) Två olika mönster för behandling av kongenital höftledsluxation *Opusc med (Stockh)* 15 357-360
- Finlay H W L, Maudsley R H & Buttsfield H I (1967) Dislocatable hip and dislocated hip in the new born infant *Brit med J* 4 377-381
- Fredensborg A (1970) Congenital dislocation of the hip. Dissertation University of Lund
- Fredensborg A, Nilsson H & von Rosen S (1977) Ett genmale *Svenska Lak Tidn* 74 110
- Hirsch C & Scheller S (1970) Results of treatment from birth of unstable hips. A 5 year follow up *Acta orthop scand Suppl* 130
- James U & Huerton T (1968) Congenital dislocation of the hip. Experiences of early diagnosis and treatment *J Bone Jt Surg* 50-B 542-545
- MacKenzie I H (1972) Congenital dislocation of the hip. The development of a regional service *J Bone Jt Surg* 54 B 18-39
- Lancet Editorial (1974) 7875 266
- Nielsen H O (1975) Kongenit höftledsluxation et 15 års materiale *Ugeskr Læg* 137 2256-2259
- Palmén K (1961) Preluxation of the hip joint *Acta paediat (Uppsala)* 50 Suppl 129
- Palmén H (1970) Preluxation of the hip in the new born. The diagnostic work in Sweden during the years 1953-1966 *Acta orthop scand Suppl* 130 8-12
- Palmén K (1975) Symposium om höftledsluxationer Svenska Läkaresällsk. Riksstämman Stockholm
- Palmén K & von Rosen S (1975) Late diagnosis dislocation of the hip joint in children *Acta orthop scand* 46 90
- von Rosen S (1970) Instability of the hip in the new born. 15 years experience in Valmo *Acta orthop scand Suppl* 130 13-23
- Severin E (1956) The incidence of congenital dislocation of the hip and pes equinovarus in Sweden *Nord Med* 55 221-223
- Williamson J (1972) Difficulties of early diagnosis and treatment of congenital dislocation of the hip in Northern Ireland *J Bone Jt Surg* 54 B 13-17

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Whatever the explanation is, the present study shows that early diagnosis in Uppsala has not been successful in one very important aspect, that is to catch all cases within the first 4 weeks of life (Table 3).

Barlow (1962) reports in his well-known paper that there is a spontaneous tendency towards stability among children with neonatal hip instability. Within 2 months about 88 per cent were stable whether treated or not. Severin's figure of 0.9 per mille CDH diagnosed after the first year of life would thus correspond to roughly eight times that in neonatal instability, i.e. 7 per mille.

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Barlow result in about $\frac{109}{8} \approx 13$ obvious

manifestations of CDH. A source of error is of course the hips considered stable by the orthopaedic consultant but treated nevertheless (68 children). Seven cases were diagnosed after the neonatal period (Table 3). Altogether at least 20 cases (13 + 7) of CDH would come out of this population, which is about 1.5 per mille. Barlow (1962) mentions approximately the same figure (1.55 per mille). The corresponding figures from 1970-1974 are as follows: 189 verified cases of in-

stability, $\frac{189}{8} \approx 23$ possible cases of CDH. Cases diagnosed after the neonatal period, three (from the non-treated group) (see Table 4) + 15 (referred from Paediatric Health Care Centres) (Table 3). Altogether about 11 cases in a population of 16,274 which is about 2.5 per mille.

The apparent difference between the calculated incidence 1.5 per mille versus 2.5 per mille is not a significant one. By using this type of calculation it is possible to bridge over the apparent differences in the figures of incidence given by Severin and those found nowadays. A calculated figure of about 2 per mille of CDH, if no treatment is instituted neonatally, seem relevant. This equals about 1.5 per cent as a reasonable figure for neonatal instability.

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The simple treatment with Frejka pillow and/or von Rosen splint has been successful in the majority of cases. Only a few cases needed plaster. Only one girl had to be operated upon. The treatment period in the von Rosen splint was generally 6 weeks and was followed by the Frejka pillow for the same length of time. The good results indicate that longer treatment in the splint is not needed (Linnéus & Undeland 1970) at least if followed by a Frejka pillow for the same time. Repeated examinations during the treatment period are necessary in order to check stability. In most cases the hip was stable at 2 weeks. Too firm a fixation with maximal abduction may be dangerous (Lancet Editorial, 1974) as illustrated by the case primarily fixed in plaster where some structural changes have been observed.

Of special interest is the handling of the cases with non-verified instability during the period 1970-1974. Out of a total of 314 cases, about one-half (161) were treated in Frejka pillows and the rest (143) were not treated. In the untreated group three subluxations were discovered later (Table 4). In the Frejka-treated group all became normal. It is possible that even those three subluxations could have been prevented if the treatment had comprised all cases. The existing "over treatment" would in that case have been more extensive. Consider-

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REFERENCES

- Artz T D, Lewis D H, Lim W G, Salvati E A & Wilson Jr P D (1975) Neonatal diagnosis, treatment and related factors of congenital dislocation of the hip. *Clin Orthop* 110 112-136.
- Barlow T G (1962) Early diagnosis and treatment of congenital dislocation of the hip. *J Bone Jt Surg* 44 B 297-301.
- Bjerkheim I (1974) Congenital dislocation of the hip joint in Norway. *Acta orthop scand Suppl* 157.
- Emnéus H (1966) Some new aspects of the treatment of congenital dislocation of the hip (CDH) according to Palmén von Rosen. *Acta orthop scand* 37 311-316.
- Finnéus M & Lindeland K (1970) Två olika mönster för behandling av kongenital höftledsluxation. *Opusc med (Stockh)* 15 357-360.
- Fnlay H W L, Maudsley R H & Busfield P I (1967) Dislocatable hip and dislocated hip in the new born infant. *Brit med J* 4 377-381.
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- Hirsch C & Scheller S (1970) Results of treatment from birth of unstable hips. A 11 year follow up. *Acta orthop scand., Suppl* 130.
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- Palmén K (1975) Symposium om höftledsluxationer. Svenska Lakarsällsk. Riksstämman Stockholm.
- Palmén K & von Rosen S (1975) Late diagnosis dislocation of the hip joint in children. *Acta orthop scand* 46 90.
- von Rosen S (1970) Instability of the hip in the new born. 15 years experience in Malmö. *Acta orthop scand., Suppl* 130 13-23.
- Severin E (1956) The incidence of congenital dislocation of the hip and pes equinovarus in Sweden. *Nord Med* 55 221-223.
- Williamson J (1972) Difficulties of early diagnosis and treatment of congenital dislocation of the hip in Northern Ireland. *J Bone Jt Surg* 54 B 13-17.

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Table 1 Pertinent data of the 13 patients with fracture of the femoral prosthesis following total hip replacement

Hospital ^{a)}	Age	Sex	Weight (kg)	Op date (month/year)	Op to fracture (months)	% ray delay (months)	Site of the fracture (mm)	The other hip	Cement thickness at calcare (mm)	Cement below the prosthesis (mm)	Lateral radio lucent zone (mm)	Appearance of lateral zone (months)	Fract of cement (months)	Position of the stem prosthesis
MGH	1	M	■	9/70	41	14	71	THR	1	25	3	13	25	varus
MGH	2	F	■	3/73	30	-	79	THR	3	40	4	3	3	varus
MGH	3	F	60	10/72	44	-	85	THR	6	50	5	5	no	neutral
MGH	4	F	85	4/70	65	3	90	OA	2	20	5	5	no	varus
MGH	5	M	90	12/70	44	2	83	OA	7	12	5	27	no	neutral
SÖS	6	M	98	11/73	14	-	72	Normal	5	30	13	13	no	varus
SÖS	7	M	115	5/69	■	-	84	THR	5	25	2	24	no	varus
SÖS	8	M	90	3/69	62	-	76	OA	5	22	5	32	no	varus
SÖS	9	M	95	4/70	40	12	■	THR	3	30	3	4	4	neutral
SÖS	10	M	102	10/70	46	13	75	OA	3	28	9	6	0	varus
SÖS	11	M	93	4/72	40	-	77	Arthrodesis	-	-	-	-	-	varus
FL	12	M	81	11/72	■	6	82	OA	0	16	3	2	no	varus
UHL	13	M	84	4/71	66	-	71	THR	13	42	2	6	no	varus
UHL	14	F	57	11/73	35	1	100	THR	13	42	2	6	no	varus

^{a)} MGH = Malmö General Hospital
 SÖS = Södersjukhuset, Stockholm
 FL = Falu Lasarett, Falun
 UHL = University Hospital, Lund

FRACTURE OF THE FEMORAL PROSTHESIS IN TOTAL HIP REPLACEMENT ACCORDING TO CHARNLEY

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An analysis of 14 fractures of the stem of the early design of low friction arthroplasty showed a predominance of heavy, bilaterally operated males. The total incidence was 0.67 per cent. The fractures occurred between 14 months and 8 years postoperatively. Every fracture was preceded by radiological signs of loosening caused by various positioning of the femoral head prosthesis and defective cement support medially at the femoral calcar.

Key words hip, arthroplasty.

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Fracture of the metallic stem of the femoral head prosthesis in total hip replacement (THR) has been reported for many prosthetic designs (Buchholz & Noack 1973, Charnley 1975, Dandy & Theodorou 1975, Leimbach & Barlow 1973, Martens et al 1974, Wilson & Scales 1973).

The low friction arthroplasty, *ad modum* Charnley, was introduced into Sweden in 1967. A questionnaire sent to the orthopaedic clinics using this method revealed 14 stem fractures. All prostheses were of the so-called first generation with a flat back. They were made of wrought air-melted 316-L stainless steel and all came from the same manufacturer (Thackray, Leeds, England). Revision operations were performed on every hip. In no instance was there any suspicion of infection at the clinical, radiographic, bacteriological or laboratory investigations.

The aim of the present investigation has been to collect the clinical details

and technical data of the 14 fractures. The analysis is based on all hips operated upon according to the method of Charnley during the period 1967-1974 in the orthopaedic departments of the General Hospital in Malmö, Södersjukhuset in Stockholm, the Central Hospital in Falun and the University Hospital in Lund.

MATERIAL AND RESULTS

A summary of the pertinent data of the 14 cases is given in Table 1.

Diagnosis

In all 14 patients the arthroplasty was a primary operation because of osteoarthritis of the hip.

Age

The age at the primary intervention ranged from 56 to 81 years. The average— 71 ± 6.8 years—did not deviate significantly from the average age of all 309 patients undergoing low friction arthroplasty at Malmö General Hospital between 1968 and 1972 (65.5 ± 9.1).

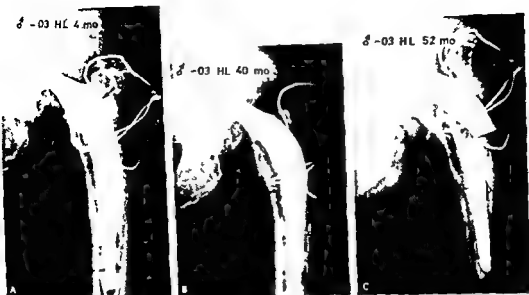


Figure 2 a) Patient no. 9, 4 months postoperatively. A radiolucent zone is already seen at the lateral proximal border of the stem. b) The same patient 40 months postoperatively. The fracture was overlooked. c) The same patient 52 months postoperatively.

Pain and trauma

The result of the primary operation was in every case excellent and all patients walked without a stick. In nine patients there was a history of slowly increasing pain in four cases preceded by a moderate trauma. The remaining five patients suddenly felt pain without any kind of trauma or previous discomfort.

Torsion of the prosthesis

At the time of this investigation six of the fractured prostheses could be traced. Of these, three were not only fractured but their proximal fragments were slightly twisted. The proximal fragment of prosthesis no. 8 was also bent.

Radiological findings

Level of the fracture. The level of the fractures as calculated from the radiographs and corrected for magnification ranged from 61 to 100 mm from the tip of the stem (average 80 ± 10 mm).

Cement support at the femoral calcar. The thickness of the cement layer between the metal and the medial cut surface of the femoral neck could be measured in 12 cases and ranged from 8 to 13 mm (average 4 ± 3). In two cases the cement did not contain radio-opaque material and therefore it was not possible to calculate the thickness.

Cement support below the tip of the stem prosthesis. In the 12 cases where radio opaque cement was used the amount of cement below the tip of the stem was measured and varied between 12 and 50 mm (average 28 ± 11 mm).

All prostheses were rigidly fixed distally in the marrow cavity.

Lateral radiolucent zone. Loosening of the femoral head prosthesis within the cement bed can be seen as a radiolucent zone at the lateral border of the proximal stem (Figure 2a). This phenomenon could be studied in 11 of the 14 hips. In two cases, non opaque cement, and in one case dislocation of the greater trochanter, made calculation impossible.

All 11 fractures were preceded by the appearance of a zone of radiolucency, which was first seen between 2 and 33 months postoperatively (average 12 ± 11 months) or between one and 81 months before fracture (average 33 ± 18 months). The maximal width of this zone measured before the fracture occurred, ranged from 2 to 13 mm (average 5 ± 3 mm).

Fracture of the cement. Fracture of the cement is another sign indicating a loose stem prosthesis. Such a fracture was seen, usually in the vicinity of the tip of the stem, in 4 of the 12 cases before the stem fractured. For the reasons previously mentioned, two hips could not be judged.

Position of the femoral head prosthesis in the

Table 2 Details of the contralateral hip in the seven patients in the fracture group with bilateral THR

Pat no	Name	The fractured side	The contralateral hip					
		Operation to fracture (months)	Operation to present date—Dec 31, 1976 (months)	Design C=Charnley B=Brunswick	Cement thickness at the calcar (mm)	Cement below the prosthesis	Position of the prosthesis	Lateral radio lucent zone (mm)
1	EN	41	55	C	1	45	varus	1
2	IV	30	38	B	0	60	varus	none
3	DJ	44	42	C	3	15	neutral	1
7	SHL	58	78	C	3	5	varus	2
9	HL	46	71	C	5	55	varus	4
13	HLI	66	76	C	2	5	varus	2
14	UH	35	38	C	4	25	varus	1

Sex

Four of the 14 fractures were in women. In the total material the female preponderance is about three to two. The difference in sex distribution between the fractured and the unfractured group is statistically significant ($P < 0.001$) (Table 3).

Weight

In order to compare the weights of patients with and without fractured stems 234 weights were sampled, distributed with regard to age and hospital in the same way as the 10 men in the fracture group. The weight of the 10 men was 94.1 ± 9.6 kg as compared with 77.0 ± 12.2 kg in the controls. The difference was highly significant ($P < 0.001$).

The other hip

Of the 14 patients seven had a THR, five osteoarthritis and one an arthrodesis on the contralateral side. In only one patient was the other hip normal.

Of the 984 patients undergoing THR at Malmö General Hospital and Södersjukhuset Stockholm between 1967 and 1974 130 were operated on both sides and in this latter group there were more fractures of the stem (the difference was significant, $P < 0.01$). In five out of seven cases the fractured side was the first operated.

As seen in Table 2 one unfractured hip had been implanted for almost as long a period as the fractured prosthesis, and the other six unfractured hips survived the fractured hips by 3 to 20 months. This could not be explained on the basis of superior surgical technique. Only in case no. 3 was the position of the stem prosthesis entirely correct on both sides.

Time of fracture

The fractures occurred between 14 months and 5 years and 6 months after the operation (average 41.5 ± 14.4 months) (Figure 1). As 7 out of the 14 fractures were overlooked at one radiographic examination the diagnosis was delayed for 1, 2, 3, 6, 12, 13 and 14 months respectively. The average delay was 7.3 months. In patient no. 4 the fracture was revealed at operation performed because of severe pain and radiographic signs of loosening of the stem prosthesis. There was no tendency for the very heavy patients to fracture their prostheses earlier.

The hips were revised between 1 month and 1 year and 9 months after the fracture.

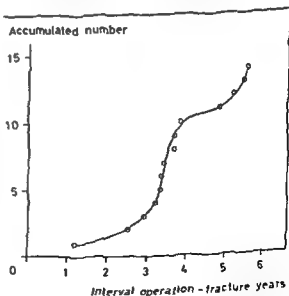


Figure 1 Accumulated number of fractured stems and year after surgery

rounded and strengthened Flanges of the proximal stem are introduced so that the prosthesis is now more able to withstand the medial directed force. At the same time the flanges prevent the stem from close bone contact anteriorly or posteriorly thus permitting a thick layer of cement around the whole stem.

The incidence 0.67 per cent is significantly above ($P < 0.01$) Charnley's (1975) 0.23 per cent incidence although he excludes fractures occurring less than 3½ years postoperatively. Considering the great risk of overlooking the fracture and the fact that the majority of the fractures appear more than 2 years postoperatively there is reason to believe that the true incidence is somewhat greater than that calculated from our observations.

The patient at risk is obviously a heavy male patient with bilateral total hip replacements with prostheses placed in varus position having weak proximal and rigid distal fixation.

The above mentioned improvements in material and design as well as improvements in surgical technique especially the valgus position will probably cause a decreased incidence of stem fractures in the future.

REFERENCES

- Amstutz H C & Markolf K L (1974) Design features in total hip replacements. The hip. *Proceedings of the Second Open Scientific Meeting of the Hip Society*. St. Louis 1974. The C. V. Mosby Co.
- Buchholz H W & Noack G (1973) Results of the total hip prosthesis design "St. Georg". *Clin Orthop* 95: 201-210.
- Charnley J (1975) Fracture of femoral prostheses in total hip replacement. *Clin Orthop* 111: 105-120.
- Dandy D J & Theodorou B C. (1975) The management of local complications of total hip replacement by the McKeel Farrar technique. *J Bone Jt Surg* 57 B: 30-35.
- Debrunner H U (1974) Der Ersatz von Gelenken unter Biomechanischen Gesichtspunkten. Biopolymere und Biomechanik von Bindegewebsystemen. 7. Wissenschaftliche Konferenz. *Deutscher Naturforscher und Ärzte* p. 461-468. Springer Verlag Berlin Heidelberg New York.
- Galaute J, Rostoker W & Doyle J (1975) Failed stems in total hip prostheses. *J Bone Jt Surg* 57 A: 230-236.
- Leinbach I & Barlow F (1973) 700 total hip replacements. *Clin Orthop* 95: 174-192.
- Martens M, Aernoudt F, deMeester P., Du Chesne P., Muller J C, deLangh R & Keste J J P (1974) Factors in the mechanical failure of the femoral component in total hip

W1

shaft Eleven stem prostheses had been placed in a varus position and the remaining three in a neutral position. None was placed in valgus.

Incidence of fracture

The incidence of fracture calculated with a minimum observation time of 2 years was 0.67 per cent. The incidence for females was 0.33 per cent and for males 1.14 per cent (Table 3).

Table 3 Number of fractured and unfractured hips in males and females at the four orthopaedic departments contributing to this investigation

	No fracture	Fracture	Total
Female	1213	4	1217 (0.33 %)
Male	860	10	870 (1.14 %)
Total	2073	14	2087 (0.67 %)

DISCUSSION

Charnley (1975) reported 17 fatigue fractures of the femoral head prosthesis and pointed to the mechanism—poor proximal and rigid distal fixation. Our findings agree entirely with this.

Possibly excluding defects of the material, fracture of the metal is merely the ultimate fate of a loosened prosthesis. When the stem is loose within the cement, the stresses in the stem increase significantly (Amstutz & Markolf 1974). This may cause fatigue or corrosion or a combination of both factors which presumably will not occur in a properly placed and cemented prosthesis.

Not one of the failed hips was infected. This is in line with the conditions necessary for fracture to occur—rigid distal fixation. In an infected femoral shaft, the zone of resorption between bone and cement increases and the femoral prosthesis, together with the surrounding cement, becomes loose within the marrow cavity. At the same time, severe pain usually prevents normal use of the hip.

At first we expected the patients with fractured stems to be younger than the

average. That this was not the case may reflect the discrepancy between chronological and biological ages as these patients were all very active. The great preponderance of men over women is presumably a reflection of their greater weight—in no case less than 81 kg.

Like Charnley (1975), we found an over-representation of bilateral arthroplasties—a most confusing finding. By measuring the wear of the socket, Charnley (1975) found no indication that the unfractured side had been noticeably spared. Could it be that a normal hip on the contralateral side spares the prosthetic hip, even when the patient is free from symptoms?

The level of the fracture and time of failure are in accordance with Charnley's (1975) findings. He also noted the risk of the fracture being overlooked at the radiographic examination, especially if this is performed soon after the fracture has occurred. This is not a catastrophe, but in three of our seven overlooked cases the diagnosis was delayed for 1 year or more. The result was unnecessary suffering for these patients. In cases with THR and pain, especially acute pain, we suggest that the possibility of stem fracture be drawn to the attention of the radiologist so that adequate exposures and projections can be obtained.

The observation that the fractured prostheses were twisted shows that important multidirectional forces act on the hip joint. Except for the vertical and medial forces, the most important is probably a posterior anterior force acting on the flexed hip joint. Here the sharp corners of the flat-backed prostheses could be weak points.

The present development in the field of metallurgy has resulted in a vacuum remelted low-carbon stainless steel with improved properties. Also the design of the low-friction arthroplasty has been considerably improved. The sharp corners have disappeared and the back is

rounded and strengthened flanges of the proximal stem are introduced so that the prosthesis is now more able to withstand the medial directed force. At the same time the flanges prevent the stem from close bone contact anteriorly or posteriorly thus permitting a thick layer of cement around the whole stem.

The incidence 0.67 per cent is significantly above ($P < 0.01$) Charnley's (1975) 0.23 per cent incidence although he excludes fractures occurring less than 3.5 years postoperatively. Considering the great risk of overlooking the fracture and the fact that the majority of the fractures appear more than 3 years postoperatively, there is reason to believe that the true incidence is somewhat greater than that calculated from our observations.

The patient at risk is obviously a heavy male patient with bilateral total hip replacements with prostheses placed in varus position having weak proximal and rigid distal fixation.

The above mentioned improvements in material and design as well as improvements in surgical technique especially the valgus position will probably cause a decreased incidence of stem fractures in the future.

REFERENCES

- Amstutz H C & Markolf K L (1974) Design features in total hip replacements. The hip. *Proceedings of the Second Open Scientific Meeting of the Hip Society*. St Louis 1974. The C V Mosby Co.
- Buchholz H W & Noack G (1973) Results of the total hip prosthesis design. *St Georg Clin Orthop* 95: 201-210.
- Charnley J (1975) Fracture of femoral prostheses in total hip replacement. *Clin Orthop* 111: 105-120.
- Dandy H J & Theodorou B C (1975) The management of local complications of total hip replacement by the McKee Farrar technique. *J Bone Jt Surg* 57 B: 30-35.
- Debrunner H U (1974) Der Ersatz von Gelenken unter biomechanischen Gesichtspunkten. Biopolymere und Biomechanik von Bindegewebssystemen. *7 Wissenschaftliche Konferenzen Deutscher Naturforscher und Ärzte* p 461-468. Springer Verlag Berlin Heidelberg New York.
- Galante J, Rostoker W & Doyle J (1975) Failed stems in total hip prostheses. *J Bone Jt Surg* 57 A: 230-236.
- Leimbach I & Barlow F (1973) 700 total hip replacements. *Clin Orthop* 95: 174-192.
- Martens M, Aernoudt E, deMeester P, Ducheyne P, Mulier J C, deLangh W & Keste lijn P (1974) Factors in the mechanical failure of the femoral component in total hip prosthesis. *Acta orthop scand* 45: 693-710.
- Wilson J & Scales J (1973) The Stanmore metal on metal total hip prostheses using a three pin type cup. *Clin Orthop* 95: 239-249.

PENETRATION OF A LONG STEM PROSTHESIS INTO THE KNEE JOINT: A COMPLICATION OF TOTAL HIP REPLACEMENT

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The unusual occurrence of penetration of the stem of a femoral prosthesis into the knee joint during total hip replacement and the method used to deal with this complication successfully, without replacing the prosthesis is described

Key words long stem prosthesis, penetration knee, complication of hip replacement

Accepted 13 vi 77

With the widespread use of total hip replacement, various complications have been reported. The entrance of cement into the knee joint and a method of preventing this complication has been reported recently (Hallel et al 1976). It is the purpose of this paper to report an unusual complication also resulting from the use of a long stem prosthesis, viz, penetration of the stem into the knee joint. The method of dealing with this complication without replacing the prosthesis is described.

CASE REPORT

A 68 year old woman with a markedly symptomatic left hip resulting from gross loosening of a Thompson femoral prosthesis was admitted for total hip replacement on June 6 1976. Because of severe osteoporosis of the femoral shaft a femoral component 28 cm long reaching the supracondylar region was used. An antero-posterior radiograph of the knee region performed during operation before injection of the cement, was considered satisfactory (Figure 1).

One week after operation when the patient started walking she complained of pain and crepitus in the left knee which was slightly swollen and tender. The patella could be rubbed against an irregular surface. On a lateral roentgenogram it was seen that the acrylic cement had extended into the knee joint and the distal end of the stem of the prosthesis had perforated the anterior cortex at the supracondylar region with its tip lying against the articular surface of the patella (Figure 2).

Arthrotomy of the knee, under tourniquet was performed 3 weeks after the joint replacement. A small irregular erosion of the articular surface of the patella was noted. The excess methyl methacrylate was removed and the cement block on either side of the projecting metallic stem was undermined to about one millimetre below the level of the anterior cortex. The joint space was isolated, the articular surfaces protected with wet sponges and a high speed saw blade mounted on a hand saw cutting tangential was used to cut off the distal end of the prosthesis flush with the anterior cortex. A small grinding stone (7 mm wide) mounted on an electric drill and fine metal files were then used to polish the cut surface making sure that there was absolutely no contact between it and the patella (Figure 3). The wound was very thoroughly irrigated before closure. The postoperative

Figure 1 Anteroposterior radiograph of the left knee at operation. There is no evidence of penetration of the knee joint in this view.



Figure 3 Lateral radiograph of the knee 3 months after operation showing the final shape of the tip of the stem and the complete absence of contact between it and the articular surface of the patella.



Figure 2 Lateral radiograph of the knee 1 week after operation. There is acrylic cement in the knee joint and penetration of the stem of the prosthesis with its tip lying against the articular surface of the patella.

course was uneventful and the patient regained full symptomless mobility of the knee joint within a short time.

DISCUSSION

Loosening of a femoral prosthesis is not an uncommon complication of conventional hip replacement. Total hip replacement is the most commonly used form of treatment. Very often a long stem prosthesis extending into the supracondylar region has to be used because of marked osteo-

porosis and to avoid fracture of the femur distal of the prosthesis

Due to the natural forward convexity of the femur, which, at times, can be quite marked, protrusion through the porotic anterior cortex should be kept in mind, and, especially when a very long stem is used, both anteroposterior and lateral radiographs should be taken. If, in spite of preoperative evaluation, the stem is found to be too long at the time of trial introduction during operation, a shorter one can be used. If, however, it is already cemented, as in the present case,

replacement of the prosthesis is difficult and since in this case arthrotomy is necessary to remove the cement from the knee joint, the method described offers a simpler and more satisfactory alternative solution.

REFERENCES

- Hallel, T., Salvati, E. A. & Botero, P. M. (1976)
Polymethylmethacrylate in the knee: A complication of total hip replacement. *J. Bone Jt. Surg.* 58 A: 556.

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IMMEDIATE WEIGHT-BEARING AFTER INTERNAL FIXATION OF FEMORAL NECK FRACTURES USING VON BAHR SCREWS

Preliminary Report of a Prospective Clinical Trial

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Osteosynthesis of displaced femoral neck fractures using von Bahr screws was performed in 50 patients. Immediate postoperative weight bearing was allowed. After a follow-up period of 1 year a high incidence (20 per cent) of early failure (dislocation of the fractures with or without screw movement) was found. Analysis of the material showed that the failure rate was influenced by the peroperative reposition of the fracture, especially the valgus/varus position of the caput fragment and the position of the screws.

Key words: femoral neck fractures, screw osteosynthesis, early weight bearing, mechanical failure.

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The primary aim when treating femoral neck fractures, especially in the elderly, is to restore the patient's prefracture state in the shortest possible time. The patient should be able to start walking exercises immediately after operation, preferably with full weight-bearing.

The failure rate following conventional internal fixation has up until now been high (for review, see Ohmann et al 1969). It seems clear that the fixation device used for the osteosynthesis affects the stability of the operated fracture, but there is no agreement regarding which type of internal fixation is the best.

This paper presents our experience gained from a prospective study of treating patients with displaced, intracapsular femoral neck fractures with internal

fixation *ad modum* von Bahr (von Bahr et al 1974) and allowing immediate weight-bearing.

PATIENTS AND METHODS

During the period from October 1974 to August 1975, 50 patients with femoral neck fractures were treated in our hospital with internal fixation *ad modum* von Bahr. There were 37 female and 13 male patients ranging in age from 15 to 87 years (mean 69.2 years).

All patients were put on tibial traction until the operation. Prophylactic anti-thrombosis therapy with either Heparin 5000 IU twice a day or Dextran VII were given. Concomitant diseases were treated when necessary. The internal fixation was performed from 1 to 26 days after admission (mean 2.8 days). (The only patient with a clinical postoperative thrombosis was operated 3 days after admission).

Operative technique. The von Bahr technique

for osteosynthesis of femoral neck fractures is a screw fixation in which two or more screws are inserted. Reduction is done with fluoroscopic monitoring with the patient on a traction table. Following reduction the lateral aspect of the proximal femur is exposed. The distal screw must be inserted first. A hole is drilled through the cortical bone and drilling is continued to the proximal fragment. The screw should be placed as steep as possible in the a.p. view and somewhat dorsal in the collum. It seems important that the distal screw is aimed a little too far distally as the screw when inserted encounters the calcar femoris and may veer off in a cranial direction. A second screw is introduced after pre-drilling approximately 3 cm proximal to the first screw. Alternatively three screws may be used: the two proximal ones must then be placed ventrally and dorsally at the same

horizontal level (care is taken to ensure that the screws are parallel in both projections (Figure 1)). A more detailed description of the technique is given by von Bahr et al (1974) and include an outline of the pitfalls of his technique.

Postoperative treatment. Postoperative X-rays were taken in the operating theatre or shortly after the operation. Mobilization with full weight bearing was started as soon as possible and Figure 2 gives the time interval from operation to postoperative walking. Physiotherapy was given both in the hospital and after discharge.

Mortality. No patient died during the operation. Postoperative mortality was recorded 1 and 6 months after operation. During the first month two patients died. One patient died during the next 5 months.

Complications. This includes all complications



Figure 1 X-rays showing von Bahr screws used in femoral neck fractures

in the first postoperative month not concerning the fracture. The complications are listed in Table 1.

No of patients

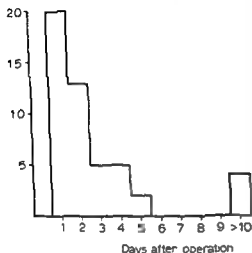


Figure 2 Number of days before weight bearing after operation (one patient died before mobilisation)

Table 1 Postoperative complications

	Complications	No of patients
Local	Deep infection	0
	Superficial infection	1
	Wound haematoma	1
General	Thrombosis/embolism	1
	Cardio pulmonary	3

RESULTS

Every patient was followed closely for the first 6 months after discharge from the hospital. All surviving patients were asked to come for a complete examination and X-ray review 1 year after the operation.

Of the original 50 patients five were dead. Eight patients had received and one was waiting for a femoral head

prosthesis, these patients were not examined. Thirty-five patients were examined in our department by one of the authors. No information is available concerning the one remaining patient.

Hip assessment Stinchfield's modification (Stinchfield et al 1957) of the Judet classification system was used. Table 2 shows the Stinchfield system and the criteria for grading clinical results. The complete results of the follow-up examinations are given in Table 3.

Range of movement The range of movement in the operated hips according to Spangfort's scheme is given in Figure 3.

Failures During the first year, 8 patients were reoperated with prosthetic replacement due to early mechanical failure of the primary osteosynthesis.

Table 2 Stinchfield's hip assessment system. Grading of disability according to pain, movement and walking ability

PAIN

Severe—loss of sleep	1
Severe when walking—unable to work	2
Moderate—able to do light work	3
Pain after effort—relieved by rest	4
Slight and intermittent	5
Absent	6

MOVEMENT

Fixed in poor position	1
Fixed in good position	2
0°–70°	3
70°–140°	4
140°–200°	5
More than 200°	6

WALKING

Impossible or almost so	1
Short distances only	2
Restricted e.g. an hour with stick	3
Long distances with stick—short without	4
No stick, but limping	5
Normal	6

CLASSIFICATION

Excellent	16 points or more
Good	12–15 points
Fair	9–11 points
Poor	8 points or less

Table 3 Results of follow-up examination based upon the patient's personal opinion (when available) and the objective hip assessment according to Stinchfield's classification system

	Classification				Unable to give personal opinion
	Excellent	Good	Fair	Poor	
Personal opinion		18	12	1	4
Hip assessment	16	12	5	2	

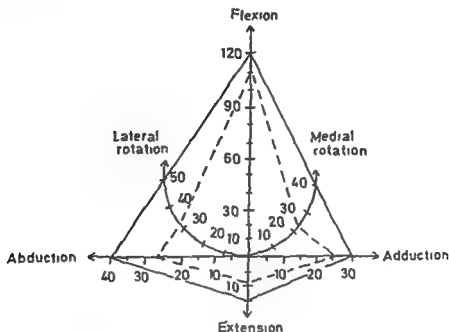


Figure 3 Range of movement in the operated hips according to Spangfort's scheme (left hip turned)

One more patient had screw movement and fracture dislocation before the follow-up examination and is waiting for prosthetic replacement. During the follow-up examination one further patient presented with dislocation of the femoral head due to screw movement, but reoperation is not indicated due to the present general condition of the patient. Thus, during the first year 10 mechanical failures were recorded giving a failure rate of 20 per cent. One patient had necrosis of the femoral head at the time of the follow-up examination.

Analysis of the material

The material was analysed to determine the factors which might have influenced the failure rate. Table 4 shows

the parameters analysed. The mechanical failures have then been compared to the rest of the material, in the following called "healed" fractures, and the results are given in Table 4. The Chi-square test was used for the statistical analysis. Due to the small number of patients in the different groups, a redistribution, as shown in Table 4, has been made to allow the statistical analysis to be performed.

The fracture types found (Garden's classification) seem to be similarly distributed in the "healed" group and in the "failure" group. However, the number of patients are small and a larger series may be necessary to confirm this distribution.

The results of the peroperative reposit-

Table 4 Analysis of the clinical material

		Healed fractures	Failures	Statistical analysis (P values)
Classification of fractures (Garden)	2 3 4	6 9 21*	0 2 8	Probably not significant
Reposition	Good Acceptable Poor	27 10 3	2 5 3	$P = 0.05$
Position of caput	Valgus Neutral Varus	24 12 4	2 0 8	$P < 0.05$
Screw position	Good Acceptable Poor	15 1 24	8 1 1	$P < 0.01$

* Original X rays are lacking for one patient

tion procedures show that the reposition in the "healed" group is significantly better than in the "failure" group. Similarly, the "healed" group shows a more favourable varus/valgus position of the caput fragment compared with the "failure" group.

The screw position has also been analysed on the basis of the criteria recommended by von Bahr (von Bahr et al 1974). The "healed" group shows a significantly better screw position than the "failure" group.

DISCUSSION

Analysis of our material indicates that the primary grade of displacement was not important as a factor causing mechanical failure, whereas the operative reduction, especially the valgus/varus position of the femoral head were of significant importance. Similarly, the analysis indicates that poor screw position gives a higher failure rate.

von Bahr has reported screw movement in 9.5 per cent of his patients.

Pseudarthrosis was also found in 9.5 per cent of his patients but he has not indicated whether this group of patients is the same as the group with screw movement. The explanation for the high failure rate (20 per cent) in our material compared with the probable low failure rate in von Bahr's series is not quite clear. In our material the patients were allowed weight-bearing from the first postoperative day, whereas von Bahr seems to have been more restrictive as regards weight bearing. Furthermore, von Bahr seems not to have excluded impacted fractures (Garden type 1) from his study as we have done. On the other hand, the results of the reposition procedure and the operative fixation (screw position) seem to be better in his material. These factors may explain the differences in failure rates.

The high incidence of mechanical failure is unacceptable. If either reduction or screw position is unsatisfactory based on the preoperative fluoroscopic view, it seems justified to advocate either a re-reposition and a new osteosynthesis or a primary prosthetic replacement. An

earlier retrospective report from this department (Søreide et al 1975) indicates that primary prosthetic replacement therapy in the elderly carries the same low mortality and morbidity rates as the internal fixation reported in this paper

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REFERENCES

- von Bohm, V, Søk H & Walheim G (1974) Osteosynthesis of femoral neck fractures using screws *Acta chir scand* 140 277-282
- Ohmann U, Bjørkegren N A & Lahlström B (1969) Fracture of the femoral neck. A five year follow up *Acta chir scand* 135 27-42
- Søreide O, Ierner, A P & Thunold J (1975) Primary prosthetic replacement in acute femoral neck fractures *Injury* 6 286-293
- Stinchfield J I, Cooperman H & Shea C F (1957) Replacement of the femoral head by Judet or Austin Moore prostheses *J Bone Jt Surg* 39 A, 1043

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UNSATISFACTORY RESULTS OF EARLY TREATMENT OF INFANTS WITH UNSTABLE HIP AT BIRTH

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Among 19864 infants born in Trondheim between 1 May 1969 and 31 December 1974 instability of the hip joint was diagnosed in 378 (1.93 per thousand live born). All infants were treated with a Frejka cushion splint usually for 3 months. In spite of this early treatment 31 infants (8.2 per cent) developed subsequent signs of CDH. In 20 children the diagnosis of CDH was based solely on radiological criteria while 11 children also displayed clinical abnormalities: most often restricted abduction of the hip joint. The prenatal and perinatal condition of the 31 children with persistent signs of CDH in spite of early treatment was compared with that of the 347 children who showed no obvious signs of CDH. The former group of patients had a relatively high frequency of hip abnormalities in their families and an increased frequency of breech presentation at birth concomitant foot deformities and instability of the hip joint also on the eighth day after birth. It is suggested that infants with unsatisfactory results from the early treatment of unstable hips constitute a separate clinical entity and an especially severe form of CDH.

Key words: hip dislocation, congenital, early treatment, unsatisfactory results.

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PATIENTS AND METHODS

On the basis of several reports (Weissman & Salama 1966, Finlay et al 1967, James & Sevastikoglou 1970, Mitchell 1972, Bjerkreim 1974, Ackermann et al 1974) it seems necessary to conclude that a certain number of infants with unstable hips at birth develop dysplasia or subluxation of the hip joint in spite of apparently correct early treatment.

The purpose of the present paper is to present the results of a detailed analysis of a group of children with unstable hips at birth in whom early therapy seemed to have failed.

Among 19864 infants born in Trondheim between 1 May 1969 and 31 December 1974 instability of the hip joint was diagnosed in 378 (1.93 per thousand live born). A detailed description of the patients has been given in a previous paper (Cyvin 1977b).

All infants with unstable hips were treated with a Frejka cushion splint usually for 3 months. In 347 patients (group B) the results of this early treatment were considered satisfactory.

Thirty-one infants (group A) subsequently developed signs of congenital dysplasia of the hip joint (CDH). The diagnosis of CDH was made before 3 months in two patients between 3 and 6 months in nine from 7 to 12 months in

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REFERENCES

- von Bahr, V, Syl, H & Walheim, G (1974) Osteosynthesis of femoral neck fractures using screws *Acta chir. scand* 140, 277-282
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KAREL BJORN CRYN

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PATIENTS AND METHODS

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All infants with unstable hips were treated with a Frejka cushion splint, usually for 3 months. In 347 patients (group B) the results of this early treatment were considered satisfactory.

Thirty-one infants (group A) subsequently developed signs of congenital dysplasia of the hip joint (CDH). The diagnosis of CDH was made before 3 months in two patients, between 3 and 6 months in nine, from 7 to 12 months in

Table 1 The criteria for the subsequent diagnosis of CDH in 31 children with unstable hips at birth

Criteria of CDH	No of patients
<i>Radiological only</i>	
Sloping of the acetabular roof and/or indistinctly marked lateral margin	11
Subluxation or luxation	3
Pathological acetabulum + subluxation	5
Retarded development of the femoral epiphysis	1
<i>Clinical + radiological (subluxation in all)</i>	20
Restricted movements of the extremity	5
Restricted movements + shortening	6
Total	31

Table 2 Prolonged therapy of 31 children with unstable hips at birth

Type of treatment	Duration in months			No of patients
	0-3	4-6	> 6	
Abduction splint	15	13	3	31
Plaster cast	4	13	14	31
Operation				6

twelve and after 12 months in eight Table 1 shows the criteria on which the diagnosis of CDH was based

In all patients in group A, prolonged treatment was instituted at the Orthopaedic Department of the Regional Hospital Table 2 shows the type and duration of the different therapeutic procedures

Information regarding the prenatal and perinatal condition of the patients was obtained from maternity unit records The following data were recorded

a) Family history of abnormalities of the hip joint and other malformations

b) The age and parity of the mother and history of previous abortions or stillbirths

c) Abnormalities of pregnancy such as proteinuria, elevated blood pressure signs of infection diabetes Rhesus immunisation administration of drugs X-ray examination or therapy and studies of placental function

d) Duration of pregnancy estimated from the date of the last menstrual period

e) The course of delivery including type of presentation, special procedures (oxytocin induction, rupture of the membranes, forceps or vacuum extraction, caesarean section), and the following complications bleeding pathological foetal heart beat, meconium stained liquor duration of delivery exceeding 24 hours, and efflux of liquor more than 12 hours before delivery

f) The birth weight, birth length head circumference, and Apgar score of the child and pathological findings such as signs of dysmaturity, hypotonia irritability, jaundice and malformations

g) The weight of the placenta and any macroscopic abnormalities, especially infarcts and calcification

h) Date of examination, name of examiner side affected, degree and duration of the instability of the hip and treatment instituted

Information regarding the subsequent management of the cases of CDH was obtained from the records of the Orthopaedic Department of the Regional Hospital

The collected data were processed in a UNIVAC 1109 computer at the Computing Centre of the University of Trondheim The mean values for group A and group B were computed Differences of means were tested by the *t* test and *P* values below 0.05 were regarded as statistically significant When indicated regression curves and confidence limits were computed A correlation coefficient of greater than 0.75 was regarded as significant

RESULTS

Table 3 shows the frequency of hip joint abnormalities in the families of infants with unsatisfactory and satisfactory results from the early treatment of unstable hips CDH occurred significantly more often in group A families than in those of group B ($P < 0.01$)

There was no significant difference in the incidence of previous abortions or stillbirths between mothers of group A and those of group B

There were no significant differences between infants in group A and those in group B in the incidence of the following gestational complications emesis, early and late bleeding, polyhydramnios anaemia pelvic instability, neurological

Table 3 Hip joint abnormalities in the families of 31 infants with persistent signs of CDH in spite of early treatment (group A) and in those of 347 early treated infants without obvious persistent abnormalities (group B)

Relatives	Group A			Group B		
	CDH	Others	Total	CDH	Others	Total
1st degree	5	0	5	34	2	36
Others	6	0	6	29	12	41
Total	11 (35.5%)	0	11	63 (18.2%)	14	77

Table 4 Course of labour in mothers of 31 infants with persistent signs of CDH in spite of early treatment (group A) and in mothers of 347 early treated infants without obvious persistent abnormalities

Course of labour	Group A		Group B	
	No	%	No	%
Spontaneous	16	51.6	243	70.0
Oxytocin induction	11	35.5	56	16.1
Rupture of membranes	2	6.5	25	7.2
Vacuum extraction forceps	3	9.7	23	7.2
Caesarean section	0	0.0	20	5.8

symptoms, blood pressure above 140/90, proteinuria, and infections

There was no significant difference between mothers of group A and those of group B in the use of the following drugs: antiemetics, diuretics, antibiotics, hormones, and sedatives

Table 4 shows the frequency of special procedures during the delivery of mothers

in group A and those in group B. Spontaneous delivery occurred significantly more often in group B than in group A, whereas oxytocin induction was instituted more often in mothers of group A than in mothers of group B. The different incidence of caesarean section in the two groups is not statistically significant.

There was no significant difference in

Table 5 The birth presentation of 31 infants with persistent signs of CDH in spite of early treatment (group A) and of 347 early treated infants without obvious persistent abnormalities

Birth presentation	Group A		Group B	
	No	%	No	%
Left occiput anterior	19	61.3	193	57.1
Right occiput anterior	2	6.5	21	6.1
Breech left sacrum anterior	4	12.9	41	11.8
Breech right sacrum posterior	1	3.2	13	3.7
Breech unspecified	0	0.0	1	0.3
Footling left sacrum anterior	1	3.2	2	0.6
Footling right sacrum posterior	1	3.2	2	0.6
Left brow	1	3.2	8	2.3
Unspecified	1	3.2	1	0.3

the complications of delivery between mothers of group A and those of group B.

In Table 5 can be seen the birth presentation of infants in group A and group B. The total frequency of breech presentation was 29.0 per cent in group A and 17.0 per cent in group B. The difference is statistically significant on the basis of the $A > B$ -hypothesis, but not on the basis of the $A \neq B$ -hypothesis.

Some of the characteristics of infants in group A and group B are shown in Table 6. Foot deformities occurred more frequently in group A than in group B ($P < 0.01$), otherwise there was no significant difference between the two groups.

Table 7 shows the sex distribution and birth rank of infants with satisfactory and unsatisfactory results from early

treatment. There was no significant difference in the sex distribution, but birth rank one occurred significantly more often in group B than in group A when the $B > A$ -hypothesis was adopted.

From Table 8 can be seen the incidence of perinatal asphyxia by the Apgar scores. There was no significant difference between infants in group A and those in group B.

Table 9 shows the results of the luxation provocation test on the first or second day of life and on the examination at the age of 1 week. Results of the first examination are similar in groups A and B. On the last examination 29 per cent of infants in group A and 11.5 per cent of infants in group B showed persistent instability of the hip joint. The difference is statistically significant ($P < 0.01$).

Table 6 Some characteristics of 31 infants with persistent signs of CDM in spite of early treatment (group A) and of 347 early treated infants without obvious persistent abnormalities (group B)

Characteristics	Group A		Group B	
	No.	%	No.	%
Foot deformities	3	9.6	6	1.7
	Mean	S.D.	Mean	S.D.
Gestation (days)	284.80	12.32	286.14	10.35
Birth weight (g)	3644.88	490.53	3618.24	498.21
Birth length (cm)	51.28	1.90	50.93	2.07
Head circumference (cm)	35.44	1.15	35.56	1.73
Weight of placenta (g)	692.06	153.50	672.82	137.84

Table 7 Sex distribution and birth rank in 31 infants with persistent signs of CDM in spite of early treatment (group A) and in 347 early treated infants without obvious persistent abnormalities (group B)

	Group A		Group B		Total	
	No.	%	No.	%	No.	%
Boys	7	22.6	86	24.8	93	24.6
Girls	24	77.4	261	75.2	285	75.4
Total	31	100.0	347	100.0	378	100.0
Birth rank one	11	35.4	178	51.3	189	50.1

Table 10 shows the correlation between the side affected at birth and the lateralisation of subsequent pathological findings in the hip. It can be seen that

in 12 infants (38.7 per cent) there was a positive correlation between the findings at birth and the late diagnosis of dysplasia.

Table 8 Appgar scores of 31 infants with persistent signs of CDH in spite of early treatment (group A) and of 337 early treated infants without obvious persistent abnormalities (group B)

Appgar scores at the age of 5 min	Group A		Group B		Total	
	No.	%	No.	%	No.	%
0-4	0	0.0	6	1.7	6	1.5
5-8	0	0.0	4	1.2	4	1.1
9-10	31	100.0	337	97.1	368	97.4
Total	31	100.0	347	100.0	378	100.0

Table 9 Results of the examination of the hip joint at birth in 31 infants with persistent signs of CDH in spite of early treatment (group A) and in 337 early treated infants without obvious persistent abnormalities (group B)

Side affected	Group A		Group B		Total	
	No.	%	No.	%	No.	%
Right	10	32.3	93	26.8	103	27.2
Left	12	38.7	138	39.8	150	39.7
Bilateral	9	29.0	116	33.4	125	33.1
Total	31	100.0	347	100.0	378	100.0
Stable on first examination	1	3.2	11	3.2	12	3.2
Persistent instability after 1 week	9	29.0	40	11.5	49	13.0

Table 10 Correlation between the side affected at birth and the localisation of the subsequent dysplasia/subluxation in 31 infants with persistent signs of CDH in spite of early treatment

Unstable hip at birth	Late dysplasia or subluxation			Total
	Right	Left	Bilateral	
Right	0	3	0	3
Left	3	3	0	6
Bilateral	3	2	4	9
Total	6	8	4	18

the complications of delivery between mothers of group A and those of group B.

In Table 5 can be seen the birth presentation of infants in group A and group B. The total frequency of breech presentation was 29.0 per cent in group A and 17.0 per cent in group B. The difference is statistically significant on the basis of the $A > B$ -hypothesis, but not on the basis of the $A \neq B$ -hypothesis.

Some of the characteristics of infants in group A and group B are shown in Table 6. Foot deformities occurred more frequently in group A than in group B ($P < 0.01$), otherwise there was no significant difference between the two groups.

Table 7 shows the sex distribution and birth rank of infants with satisfactory and unsatisfactory results from early

treatment. There was no significant difference in the sex distribution, but birth rank one occurred significantly more often in group B than in group A when the $B > A$ -hypothesis was adopted.

From Table 8 can be seen the incidence of perinatal asphyxia by the Apgar scores. There was no significant difference between infants in group A and those in group B.

Table 9 shows the results of the luxation provocation test on the first or second day of life and on the examination at the age of 1 week. Results of the first examination are similar in groups A and B. On the last examination 29 per cent of infants in group A and 11.5 per cent of infants in group B showed persistent instability of the hip joint. The difference is statistically significant ($P < 0.01$).

Table 5 Some characteristics of 31 infants with persistent signs of DII in spite of early treatment (group A) and of 347 early treated infants without obvious persistent abnormalities (group B)

Characteristics	Group A		Group B	
	No.	%	No.	%
Foot deformities	3	9.7	6	1.7
	Mean	S.D.	Mean	S.D.
Gestation (days)	284.80	12.32	286.14	10.35
Birth weight (g)	3644.88	490.63	3618.24	498.21
Birth length (cm)	51.28	1.90	50.93	2.07
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	No.	%	No.	%	No.	%
Boys	7	22.6	86	24.8	93	24.6
Girls	24	77.4	261	75.2	285	75.4
Total	31	100.0	347	100.0	378	100.0
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TRABECULAR ARCHITECTURE OF THE KNEE JOINT

HIDEO TAKECHI

Department of Rehabilitation Medicine Okayama
University Medical School, Okayama Japan.

The trabecular architecture of the human knee joint was studied three dimensionally by microradiography. The trabecular arrangement of the two condylar wheels of the femur was divided into five types. The trabeculae are so arranged that both condyles are able to adjust to mechanical compression and rotary movement. In the tibia, each trabecular arrangement has a different mechanical function. The epiphyseal line can be considered a laminated structure interposed between the compressive forces acting from the articular surface and the forces supporting the architecture of the metaphysis. The mechanics and kinematics of the trabecular architecture are discussed.

Key words: trabecular architecture, knee joint, microradiography

Accepted 10.11.77

Various attempts have been made to analyze the trabecular structure of the upper end of the femur. The oldest model is Ward's triangle (*triangulum internum femoris*) described in 1838 in which it was likened to a dermch supporting a load. The trabecular architecture of the femoral head and neck has been used in biomechanical analysis of osteoarthritic alterations of the hip, internal fixations of fractures, osteotomy of the proximal femur and in total hip replacement. However, the trabecular architecture of the knee joint has not been analyzed in a similar fashion. The purpose of this paper is to describe knee trabecular architecture as observed by microradiography.

MATERIAL AND METHODS

Six complete adult knee joints were obtained from amputated limbs. The patients ranged from 30 to 60 years of age. The specimens were fixed

in 10 per cent formalin for 1 week, and the soft tissues were removed from the femur, tibia and patella. The specimens were washed in water for 24 hours, defatted in trichloroethylene for 72 hours, dehydrated for 24 hours in a graded series of 70, 90 and 99 per cent ethyl alcohol, dried at room temperature for 4 hours and embedded in polyester resin. The embedded specimens were cut into serial sections, using a high speed cutter, in the horizontal, sagittal and frontal planes. The sectioned specimens were treated with 2 per cent sodium hypochlorite solution for 20 minutes to remove the protein. The embedded resin was removed manually and the bone sections were examined by microradiography. The microradiographic apparatus used was type CMB, Nippon Soft-X Co (Tokyo). Roentgenograms were taken at 30 kVp, 25 mA for 90 seconds at a distance of 70 cm.

RESULTS

The femur and tibia trabeculae showed different patterns of arrangement on either side of the epiphyseal line on sagittal sections. Below the epiphyseal line in the femur, the trabeculae were gen-

- of treatment with results *Clin Orthop* 86 21-27
- James U & Sevastikoglou J A (1970) Analysis of a material of congenital dislocation of the hip *Acta orthop scand* Suppl 130 30-35
- Komprda J (1974) Diagnostika vrožené dysplazie kyčle u novorozenců *Acta Chir orthop Traum cech* 41 448-455
- Lauritzen J (1971) Treatment of congenital dislocation of the hip in the newborn *Acta orthop scand* 42 259-267
- Mitchell G P (1972) Problems in the early diagnosis and management of congenital dislocation of the hip *J Bone Jt Surg* 54 B 4-12
- Moore I H (1974) Screening for congenital dislocation of the hip *J Irish med Ass* 67 104-107
- Palmén K (1961) Preluxation of the hip joint *Acta paediat scand* Suppl 129 1-71
- von Rosen S (1970) Instability of the hip in the newborn. Fifteen years experience in Malm *Acta orthop scand* Suppl 130 13-24
- Sommer J (1971) Atypical click in the newborn *Acta orthop scand* 42 353-356
- Stohr A (1972) Beschreibung eines die Prognose der Luxationshüfte beeinflussenden biologischen Faktors *Beitr Orthop Traum* 19 331-339
- Uher M (1972) Skúsenosti z vyšetřování kyčlí na novorozenečím oddělení *Acta Chir orthop Traum cech* 39 161-163
- Weissmann S I & Salama R (1966) Treatment of congenital dislocation of the hip in the newborn infant *J Bone Jt Surg* 48 A 1319-1327
- Wilkinson J A (1972) A post natal survey for congenital displacement of the hip *J Bone Jt Surg* 54 B 40-49
- Wynne Davies R (1970) Acetabular dysplasia and familial joint laxity: two etiological factors in congenital dislocation of the hip. A review of 589 patients and their families *J Bone Jt Surg* 52 B 704-710

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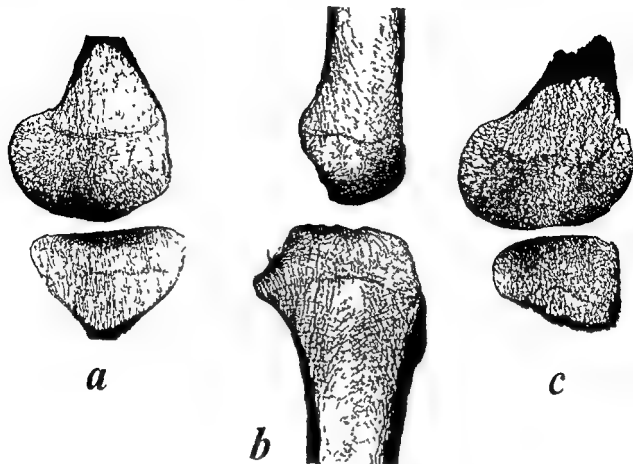


Figure 1 Sagittal sections of the knee joint, 40-year old female a medial section, b middle section, c lateral section

erally arranged perpendicular to the articular surface. In the medial and lateral condyles, dense orientations of the trabeculae ran directly from the middle and somewhat posterior region of the epiphyseal line to the posterior joint surface. This trabecular orientation had an anterior inclination of 20° to the femoral axis. Trabeculae located posterior to this region were arranged perpendicular to the joint surface in both condyles. However, trabeculae located in the anterior area displayed different patterns in the medial and lateral condyle. Trabeculae in the medial condyle were mainly arranged perpendicular to the joint surface toward the epiphyseal line. These trabeculae were fine and dense for 5–10 mm from the articular surface, and then thick and coarse toward the epiphyseal line. These thick and coarse trabeculae

were connected by fine transverse trabeculae. In the lateral condyle, the trabeculae were also arranged perpendicular to the articular surface but did not reach the epiphyseal line, and these trabeculae were consistently thick and dense. No definite trabecular orientation was present in the region surrounded by the posterior trabeculae, the anterior trabeculae and the epiphyseal line.

In these sagittal sections the profile of the medial condyle was more circular and the lateral condyle was more ellipsoidal in shape (Figure 1). As the wheels of both condyles were not parallel to the sagittal plane, both condyles were sectioned in the plane parallel to the wheel. The medial sections of the medial condyle (Figure 2) were more circular but at the center of the wheel a more ellipsoidal contour was present. In cut-sections



Figure 2 Sections of the condylar wheels, 36 year old male a medial condyle b lateral condyle

near the intercondylar notch the contour was ellipsoid-shaped with a flattened anterior surface. The contour of the lateral condyle was more smoothly ellipsoidal. The trabecular arrangement of the condylar wheels was similar in both condyles. The previously described trabeculae with 20° inclination were also evident in both condyles. From the patellar surface of the condyles, the fine and dense perpendicular trabeculae were arranged toward the epiphyseal line. These trabeculae were arranged more horizontally in the medial than in the lateral condyle. In the central area of these wheels the trabeculae formed an irregular network. These trabeculae were thick and coarse in the medial condyle but fine and dense in the lateral condyle. The irregularly shaped intercondylar notch showed articular cartilage in the anterior half. The trabeculae were perpendicular to the surface in the anterior half but formed a network in the posterior half. Above the epiphyseal line, the trabeculae were parallel to the femoral axis in both condyles. However, sections of the intercondylar notch showed two groups of trabeculae crossing each other: those running from

the antero-superior cortex to the postero-inferior cortex and those from the postero-superior cortex to the antero-inferior cortex.

Sagittal sections of the patella showed two groups of trabeculae (Figure 3). The first group was arranged perpendicular to the articular surface in a rather postero-anterior direction and the second group ran along the anterior contour at intervals of 4 mm.

Trabeculae of the tibia were arranged perpendicular to the joint surface in both condyles and they were parallel to the tibial axis. However, sagittal sections of the middle area of the tibial tuberosity showed four definite groups of trabecular arrangement: (1) from the tibial tuberosity to the posterior articular surface, (2) from the posterior cortex to the posterior articular surface and eminence, (3) from the tibial tuberosity downward to the posterior cortex and (4) from the anterior cortex upward to the posterior margin of the metaphysis. The trabeculae of the first group were finer than those of the other groups, and the latter two groups crossed each other in the metaphysis.

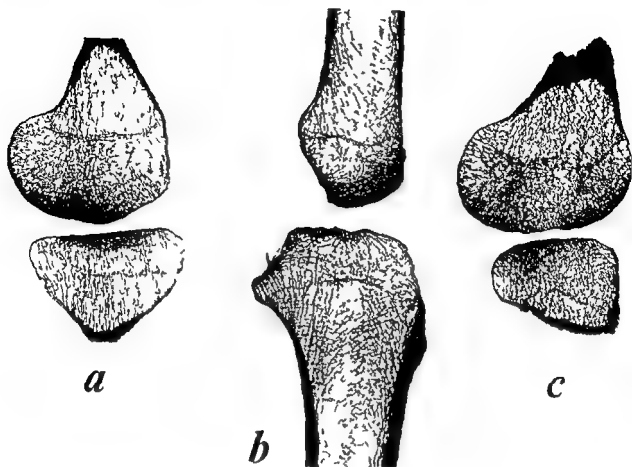


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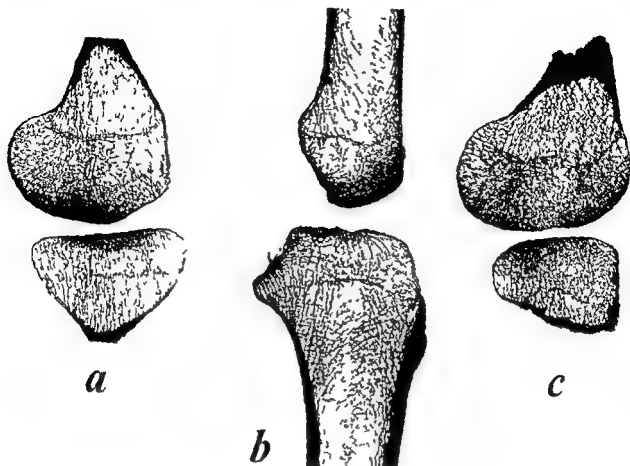


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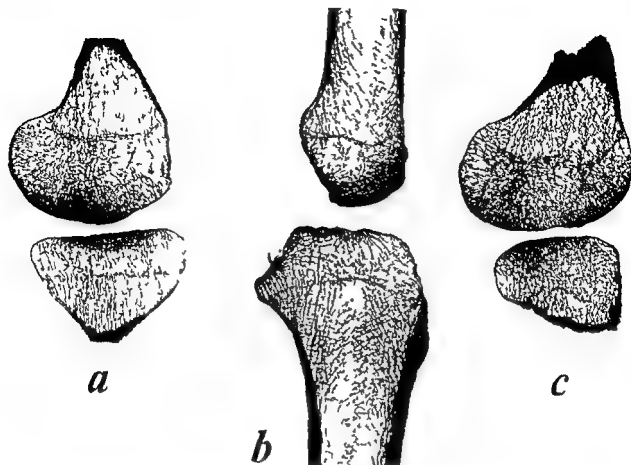


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Figure 5 Horizontal sections of the femur, 34 year-old male. *a* section below the epiphyseal line, *b* section above the epiphyseal line



Figure 6 Horizontal sections of the tibia 33-year-old male. *a* section above the epiphyseal line, *b* section below the epiphyseal line

surface and the trabeculae were arranged parallel to the outer contour of the condyles. The trabeculae perpendicular to the posterior surface were fine and dense near the joint surfaces, but thick and coarse in the region between the joint surfaces. The second type of trabecular arrangement was found near the patellar surface and was oriented parallel to the anterior contour, crossing the first type of trabeculae. The third

type of trabecular arrangement radiated from the intercondylar notch out to both sides, crossing the first type of trabeculae. The central area of the femur surrounded by the first, second and third trabecular arrangements was rather coarse and irregularly oriented. The fourth type of trabecular arrangement consisted of fine and short trabeculae radiating from both collateral ligament attachments.



Figure 3 Sections of the patella a sagittal section 40 year old female, b frontal section 60 year old male, c horizontal section 34-year-old male



Figure 4 Frontal sections of the knee joint 60 year-old male a anterior section b middle section c posterior section

In frontal sections of the femur and tibia, the trabeculae were usually arranged perpendicular to the joint surface and parallel to the bone axis (Figure 4). They were thicker and coarser near the epiphyseal line from the joint surface, and finer and denser toward the metaphysis. Other trabeculae radiated from the intercondylar notch toward both condyles.

Frontal sections of the patella showed

an irregular trabecular network (Figure 3).

Horizontal sections of the femoral condyles showed the direction of the condylar wheels (Figure 5). The patello-femoral articulation was also observed in these sections. All horizontal sections of the femoral condyle showed four patterns of trabecular orientation. The first pattern was from the posterior articular surface of both condyles to the patellar



Figure 5 Horizontal sections of the femur 35-year old male. a section below the epiphyseal line, b section above the epiphyseal line

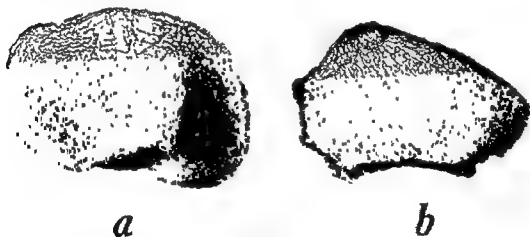


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Horizontal sections of the patella showed three types of trabecular arrangement. The first was fine, ran antero-posteriorly and was perpendicular to the joint surface. The second trabecular group was arranged along the anterior contour at intervals of about 4 mm. The third type was present mainly at the lateral joint surface and was arranged parallel to the contour at intervals of 4-5 mm (Figure 3).

Horizontal sections of the tibia near the articular surface showed a fine trabecular network with a transverse orientation in the anterior area and a radial orientation in the posterior area (Figure 6). Four groups of trabecular arrangement were found in sections containing the tibial tuberosity. The first group ran from the lateral cortex to the tibial tuberosity, the second from the postero-medial cortex to the tibial tuberosity, the third from the posterior cortex to the antero-lateral cortex and the fourth from the posterior cortex to the antero-medial cortex.

DISCUSSION

The architecture of cancellous bone has been studied for the past one hundred years. In 1867, Meyer observed the architecture of the upper end of the femur and described two kinds of trabecular arrangement, viz., tension trajectories and pressure trajectories which intersected at right angles. In 1869, Wolff demonstrated the relation between architecture and function of bone and emphasized that the major trabecular patterns intersect at right angles (orthogonality). Roux (1895) agreed with Wolff's opinion and stated that cancellous bone is built trajectorially.

These theories have been called "the trajectorial theory". The term "trajectory" has been used for a single bone trabecula with a definite orientation corresponding to stress. Gebhardt (1910)

and Petersen (1927) studied the same subject.

However, in 1920, Jansen pointed out that most of the previous investigators considered that the static pressure of the body weight played the predominant role in bone formation. He suggested that muscle tension had an equally strong deciding influence on the architecture of cancellous bone. In 1929, Carey stated that the architecture of cancellous bone was the result of pressure factors from muscle action rather than the static pressure of body weight. Both Jansen and Carey believed that the major trabeculae do not intersect at right angles.

Recently, Pauwels (1973) proved that the classical trajectorial theory is a valid principle for bone architecture in the upper end of the femur.

On the other hand, in 1922, Triepel (1922a) stated that the internal bone architecture was in basic harmony with the outer contour though further modifications were due to mechanical stress. Triepel's theory was that the trabeculae supported the outer contour of the bone.

Although most of these studies were carried out on the upper end of the femur, it appears to have been accepted that trajectorial architecture was observed in every cancellous bone. Observations of the trabecular patterns in the lower end of the femur have only been reported by a few authors. Koch (1917) studied trabecular architecture in this part using a few three dimensional sections and concluded that all trabeculae arising from the joint surface were perpendicular to it. Jansen (1920) observed the diverging trabeculae radiating from the intercondylar notch and suggested that these might be the result of some rotational force acting on the tibia. Triepel (1922b) found that the cut-surface of the femoral condyles displayed two trabecular orientations: one running straight from the posterior area diverging to the distal anterior region and the other run-

ning from the anterior area curving along the outer contour of the condyles to the posterior area. He thought that these orientations corresponded with the cut surfaces of his "contour-forming trabecular sheets". Maquet (1976) studied the trabecular architecture of the femoral condyles using a photoelastic model of frontal and horizontal planes as well as horizontal X-ray pictures and supported the trajectorial theory. Descriptions of the trabecular architecture in the frontal and horizontal plane by Koch, Jansen, Triepel and Maquet were almost the same.

The present study also found trajectories in the frontal and horizontal sections of the femoral condyles as previous investigators have mentioned. These findings suggest that the static pressure of the body weight is important and support the trajectorial theory as did Maquet's findings. However, the precise architecture of both the condylar wheels should be studied in the sagittal plane in order to analyze the relation between their architecture and function. In the usual lateral view of X-ray examinations both femoral condyles and the intercondylar notch are superimposed so that the detailed trabecular architecture cannot be obtained. By contrast, the trabecular architecture of the condylar wheels can be revealed by microradiographic techniques using the recent advances in calcified material preparation. The present study showed that the internal structure of the condylar wheels is influenced by rotary movement in the sagittal plane. Moreover, the plane of the cross-section was made parallel to the direction of each condylar wheel of the femur in this study because both the condylar wheels of the femur induce rotary movement of the knee joint. The five trabecular arrangements in the sagittal sections are shown in Figure 7.

1 The central network just below the epiphyseal line. These trabeculae were

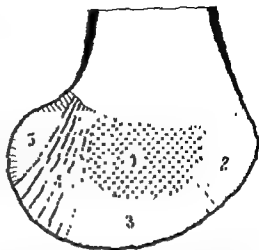


Figure 7 Schematic illustration of the trabecular arrangement of the condylar wheel. 1 Central network. 2 Anterior perpendicular trabeculae. 3 Inferior perpendicular trabeculae. 4 Trabeculae with an anterior inclination. 5 Posterior trabeculae.

the same as the transverse trabeculae observed on vertical cut surfaces radiating from the intercondylar notch to both condyles in both horizontal and frontal sections.

2 The perpendicular trabeculae running from the anterior patello-femoral articular surface to the central network.

3 The perpendicular trabeculae at the bottom of the wheels. They run from the tibio-femoral weight-bearing surface to the central network.

4 Trabeculae with an anterior inclination of 20°.

5 The fine and dense trabeculae seen at the posterior margins of both condyles.

Trabecular arrangement 1 can be likened to the axis of a wheel and trabecular arrangement 3 can be compared to the spokes of a wheel. Arrangement 2 resists compression exerted by the patella, arrangement 4 supports both the weight-bearing force and the outer contour of the bone, and arrangement 5 supports the outer contour. Some trabeculae perpendicular to the joint surface prob-

Horizontal sections of the patella showed three types of trabecular arrangement. The first was fine, ran antero-posteriorly and was perpendicular to the joint surface. The second trabecular group was arranged along the anterior contour at intervals of about 4 mm. The third type was present mainly at the lateral joint surface and was arranged parallel to the contour at intervals of 4-5 mm (Figure 3).

Horizontal sections of the tibia near the articular surface showed a fine trabecular network with a transverse orientation in the anterior area and a radial orientation in the posterior area (Figure 6). Four groups of trabecular arrangement were found in sections containing the tibial tuberosity. The first group ran from the lateral cortex to the tibial tuberosity, the second from the postero-medial cortex to the tibial tuberosity, the third from the posterior cortex to the antero-lateral cortex and the fourth from the posterior cortex to the antero-medial cortex.

DISCUSSION

The architecture of cancellous bone has been studied for the past one hundred years. In 1867, Meyer observed the architecture of the upper end of the femur and described two kinds of trabecular arrangement, viz, tension trajectories and pressure trajectories which intersected at right angles. In 1869, Wolff demonstrated the relation between architecture and function of bone and emphasized that the major trabecular patterns intersect at right angles (orthogonality). Roux (1895) agreed with Wolff's opinion and stated that cancellous bone is built trajectorially.

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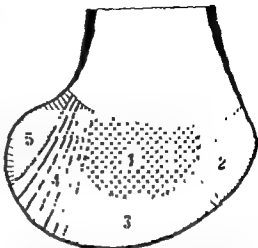


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ably do not radiate from the axis as the shape of the condylar wheels is not circular. Nevertheless, the present findings demonstrate that both condyles are adjusted to mechanical compression and the rotary movements of the condylar wheels. From these observations it would seem to be difficult to adapt the trajectory theory to explain the architecture of the condylar wheels.

The present results further indicate that the trabeculae perpendicular to the joint surfaces of both tibial condyles support compression from both condylar wheels of the femur. However, sections containing the tibial tuberosity present a different trabecular arrangement. In 1900, Albert described the trabecular arrangement in these areas as consisting of two groups of trabeculae, viz., an anterior band from the lower posterior cortex to the eminentia and the anterior articular surface, and a posterior band from the lower anterior cortex to the eminentia and the posterior articular surface. He also mentioned that these two bands cross each other at right angles. His study supported the trajectory theory. The present study also showed trajectories but the trabecular arrangement can be divided into four groups (Figure 8). The first and third groups are constructed to resist tension from the M quadriceps femoris at the tibial tuberosity and the fourth group to resist tension from the hamstrings. The second trabecular group as well as the posterior half of the first group support compression by acting on the articular surface. Thus, each trabecular arrangement has a different mechanical function. The first and second groups seen in horizontal sections support tension exerted at the tibial tuberosity and the third and fourth groups support the outer contour of the bone.

It was also shown that there are fine and dense trabeculae converging toward the epiphyseal line from the metaphysis

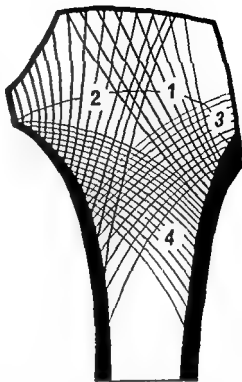


Figure 8 Schematic illustration of the trabecular arrangement of the tibia at the tibial tuberosity. 1 Trabeculae from the tibial tuberosity to the posterior articular surface. 2 Trabeculae from the posterior cortex to the posterior articular surface and eminentia. 3 Trabeculae from the tibial tuberosity inferior to the posterior cortex. 4 Trabeculae from the anterior cortex superior to the posterior margin of the metaphysis.

of both the femur and tibia. The epiphyseal line can be considered a laminated structure interposed between the compressive forces acting from the articular surface and the forces supporting the architecture of the metaphysis.

In 1975, Raux et al. analysed the trabecular architecture of the patella at the microscopic level and concluded that the predominant trabecular elements were the oriented sheets of hard tissue connected laterally by rods of the same structure. In the present study, the main trabeculae of the patella observed in the sagittal and horizontal sections can be said to support compression by acting on the femoral joint surface. The network seen in the frontal sections probably corresponds to the cut surface of these trabeculae. The thick and dense anterior

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The thickness and density of the trabeculae are probably determined by the degree of compression and tension, and the trabecular orientations are probably determined by stresses. Theoretically, the trabecular architecture can be thought of as a kind of rigid frame in solid mechanics. The elements of this rigid frame are the trabeculae which are made of osseous tissue, a kind of composite material. The crossing patterns of this rigid frame are not always rectangular as described in the trajectorial theory and seem to be rectangular only where static pressure plays the predominant role. It appears possible to use the finite element method of solid mechanics for examining the mechanical characteristics of the trabecular architecture.

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REFERENCES

- Albert F (1900) Die Architektur der Tibia. *Wien med Wochr* 50: 162, 163, 220, 221, 266-274.
- Carty E J (1929) Studies in the dynamics of histogenesis. *Radiology* 13: 127-168.
- Gebhart W (1910) Ueber die funktionelle knochengestalt. *Verh dtsch Ges Orthop Chir* 27: 121, 220.
- Jansen M (1920) On bone formation its relation to tension and pressure. Manchester Univ Press, London.
- Koch J (1917) The law of bone architecture. *Amer J Anat* 21: 177, 298.
- Maquet P (1976) *Biomechanics of the knee*. Springer-Verlag, Berlin Heidelberg New York.
- Meyer H (1867) Die Architektur der Spongiosa. *Reichert & du Bois Reymond Arch Anat Physiol & Wissenschaftl Med Jhg* 1867: pp 615-628.
- Pauwels F (1973) Kurzer Ueberblick über die mechanische Beanspruchung des Knochens und ihre Bedeutung für die funktionelle Anpassung. *Z Orthop* 111: 681, 705.
- Petersen H (1927) Über den Feinbau der menschlichen Skeletteile. *Arch Entwickl Mech Org* 112: 112, 141.
- Roux W (1905) *Gesammelte Abhandlungen über Entwicklungsmechanik der Organismen*. Bd I, pp 458-756. Verlag von Wilhelm Engelmann, Leipzig.
- Triepeil H (1922a) Die Architektur der Knochenspongiosa in neuer Auffassung. *Z menschl Vererb u konstit Lehre* 8: 269, 311.
- Triepeil H (1922b) *Die Architekturen der menschlichen Knochenspongiosa. Atlas und Text*. Verlag von J F Bergmann, München und Wiesbaden.
- Wolff J (1869) Ueber die Bedeutung der Architektur der spongösen Substanz für die Frage vom Knochenwachstum. *Chl med Wiss* 7: 849, 851.

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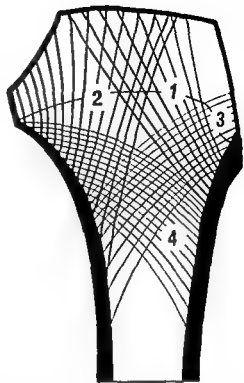


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REFERENCES

- Albert P (1899) Die Architektur der Tibia. *Monatsh. med. Naturh.* 50: 162-173, 270-274, 266-273.

- Carey P J (1929) Studies in the dynamics of histogenesis. *Radiology* 13: 127-168.
- Gebhart W (1910) *Leber die funktionelle Knochengestalt Verh. dtsch. Ges. Orthop. Chir.* 27: 121-220.
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- Koch J (1917) The law of bone architecture. *Amer. J. Anat.* 21: 177-298.
- Maquet P (1976) *Biomechanics of the knee*. Springer-Verlag, Berlin-Heidelberg-New York.
- Meyer H (1867) Die Architektur der spongiosa. *Reichert & du Bois-Reymond Arch. Anat. Physiol. & Wissenschaftl. Med. Jhg.* 1867: pp. 615-678.
- Paunells F (1973) Kurzer Überblick über die mechanische Beanspruchung des Knochens und ihre Bedeutung für die funktionelle Anpassung. *Z. Orthop.* 111: 681-700.
- Petersen H (1927) Über den Feinbau der menschlichen Skeletteile. *Arch. Entwickl. Mech. Org.* 112: 112-143.
- Raut P, Townsend P R, Miegel H, Rose R W & Radin F L (1975) Trabecular architecture of the human patella. *J. Biomech.* 8: 1-7.
- Stur W (1892) *Gesammelte Abhandlungen über Entwicklungsmechanik der Organismen*. Bd. 1, pp. 458-756. Verlag von Wilhelm Engelmann, Leipzig.
- Triepel H (1922a) Die Architektur der Knorpel-spongiosa in neuer Auffassung. *Z. menschl. Vererb. u. konstitt. Lehre* 8: 279-311.
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OSTEOCHONDRITIS DISSECANS

A Histologic and Autoradiographic Study in Man

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Surgically excised cylindrical specimens from 14 adult patients with osteochondritis dissecans in the knee joint were studied with histologic and autoradiographic techniques. The lesions were found to be composed of normal hyaline cartilage with no pathological changes. In the bone part of the specimens there were well defined fissures at various distances from the tidemark. On both sides of the fissure but especially on the OD side, there were scattered osteonecroses in complete disarray. No tetracycline fluorescence activity could be seen in the lesions.

Key words osteochondritis dissecans, autoradiography, fluorescent microscopy

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More than 100 years have elapsed since Sir James Paget in 1870 described osteochondritis dissecans (OD) and called it "quiet necrosis". König in 1887 first used the name OD for lesions he had seen in the human knee. Since these first descriptions of the lesion, many theories have been put forward as to its etiology. Several etiologic factors, i.e., trauma, ischemia and hereditary abnormalities of ossification have been suggested.

The condition has been described in animals (Reiland 1975). Here the primary disease is in the epiphyseal cartilage with secondary changes in the bone (Olsson 1976). But most authors consider that in human beings there is primarily a separation of a cartilage-bone

fragment from the subchondral bone (Conway 1937, Smillie 1960, Aichroth 1971 a).

Although the long-term course of the disease has been clarified by Lindén (1976), morphological studies have so far been sparse. Scintimetric studies *in vivo* (Lindén & Nilsson 1976) have shown a very moderate, increased radioactive uptake in the lesion. No autoradiographs or fluorochromic studies of OD have been published.

The purpose of the present investigation was to submit a histologic and autoradiographic study of the cartilage and the bone in OD in adults.

MATERIAL AND METHODS

The series consisted of 14 patients (9 men and 5 women) aged 15-33 years (average 20 years). The patients had had symptoms of OD in the

nee joints for periods ranging from 9 months to 17 years (average 4.9 years). The lesions were in situ in the medial femoral condyles in 10 knee joints. In another four joints the fragment had left the condyle.

Five days before the operation, nine patients received a peroral dose of tetracycline 1 g daily.

Two or three cylindrical biopsy specimens 2 mm in diameter were obtained at operation from the osteochondritic lesion of all the knee joints. The specimens comprised articular cartilage and subchondral bone. The biopsies were immediately placed in 10 ml of Eagles solution (37°C) containing 50 μ Ci 3 H thymidine and shaken for 3 hours. One of the sections was washed in physiologic saline solution and fixed in 10 per cent neutral buffered formalin decalcified in 40 per cent formic acid and 20 per cent sodium citrate. The decalcified section was embedded in paraffin. Sections for histologic and autoradiographic study were prepared to a thickness of 7 μ , and stained with hematoxylin-eosin, Safranin O, toluidine blue, and according to van Gieson. Autoradiographs of routine histological sections 7 μ thick were prepared according to the dipping method with Ilford K2 liquid emulsion. After 3 weeks exposure the autoradiographs were developed in Gevaert X-ray developer G250 and fixed in Gevaert X-ray fixer G30. The sections were stained through the emulsion with Mayer's hematoxylin. The second slice was fixed in formalin, dehydrated and embedded in methylmethacrylate without decalcification. Sections 7 μ thick were cut with a bone microtome. These sections were stained with Goldner stain (Schenk, 1965) and examined for osteoid tissue. One part of the second slice was left unstained for fluorescent microscopy.

RESULTS

No thymidine-labeled chondrocytes were found in the autoradiographic preparations. The number, the orientation and the appearance of the chondrocytes in the hyaline articular cartilage were within normal limits.

Hematoxylin-eosin stained sections, and sections stained according to van Gieson, showed normal hyaline articular cartilage. Safranin O staining demonstrating the content of glycosaminoglycans in the cartilage varied from none at all to very deep staining in the different preparations. The nuclei of chon-

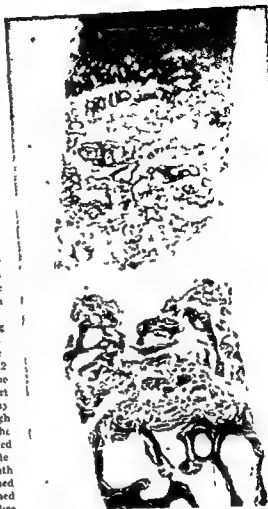


Figure 1 Surgically excised cylindrical specimens from osteochondritis dissecans lesion in a knee joint. On the top the columnar and basal layer of the hyaline cartilage with a normal appearance. In the bone part a clear fissure is seen with disorganization and osteonecrosis on both sides (Goldner $\times 1$).

drocytes in the cartilage were normal as seen with toluidine-blue staining. The appearance of the hyaline articular cartilage was that of normal viable laying over an ossific nuclei. No clefts were seen. In the preparations from the four patients with empty beds the bottom was covered with fibrous cartilage of varying thickness.

In the ossific part a well-defined fis-



Figure 2 The same specimens as in Figure 1. On both sides of the fissure new mesenchymal tissue has formed (Goldner $\times 25$)

sure was found in the bone located, in different specimens, at a varying distance from the overlying articular cartilage. The fissure was situated immediately under the hyaline articular cartilage in one preparation, but in another at a distance of up to 10 mm from the tide-mark in the articular cartilage (Figure 1). On both sides of the fissure, but especially in the detached fragment there were islands of necrotic bone with disorganization of the trabeculae in the form of fragmentation, but also coarse and clumsy trabeculae. Some of the lacunae were empty, but normal osteocytes could also be seen in the lacunae (Figure 2). Both osteoblastic and osteoclastic activity were observed. In preparations stained according to Goldner, an increased number of osteoid seams near the fissure could be visualized on both its sides.

In some preparations newly formed connective tissue, at various stages of differentiation, had begun to fill out the fissure. In some, this differentiation had gone so far as to be fibrous cartilage as seen with toluidine-blue staining.

Further from the fissure the bone became more normal on both sides with normal marrow and gracile trabeculae with lacunae accompanied by osteocytes. No osteoid seams could be seen here.

With fluorescent microscopy no tetracycline labeling was visible in the bony part of the osteochondritic lesion.

DISCUSSION

Osteochondritis dissecans may be defined as a partial or complete separation of a cartilage-bone fragment from a joint with the separation of the fragment from the surrounding tissue taking place gradually (Smilie 1960).

The cause of this separation being obscure, no theory is fully accepted. The hypothesis of *ischemia* postulates an interruption of the blood supply to an area of subchondral bone, which would then lead to sequestration of the bone together with the overlying articular cartilage (Riegan 1920, Axhausen 1922, Watson-Jones 1952). This interruption is supposed to be caused by emboli of fat, bacteria or red corpuscle aggregation.

Some form of osteonecrosis has been postulated. The osteonecrosis may appear as the result of an interrupted blood supply consequent upon traumatic squashing without fracture of the articular bone end (Roessner 1922, Jaffe 1972).

The hypothesis of *trauma* has been accepted by various authors, from the first investigation of König in 1887 up to the present time. The trauma can be an impact of the bone by the opposing joint surface (Axhausen 1914), rotating forces (Kappus 1920), bone impression of the

patella (Hellstrom 1922), or injuries from the eminentia intercondyloidea (Fairbank 1933, Smilie 1960, Scheller 1960).

There is a certain amount of experimental support for the traumatic hypothesis (Rehbein 1950, Langenskiöld 1955, Tallquist 1962, Aichroth 1971 a). Indeed, there is no clear borderline between OD and an old osteochondral fracture, although by definition the osteochondral fracture occurs momentarily in conjunction with trauma and hemarthrosis (Aichroth 1971 b).

In animals, the basic feature of OD is a disturbance of endochondral ossification. The lesion is primarily located in the cartilage of the joints and the growth plate thus becoming thicker than normal and dying in the deepest layers. Cracks and fissures occur, and synovial fluid gets into the cracks and reaches subchondral bone causing inflammation in the joint (Olsson 1976).

In a histologic and microradiographic analysis of surgically excised lesions Chiroff & Cooke (1970) postulated that the bone of the ossific nucleus was newly formed and not merely separated from the femoral condyle by trauma.

This investigation demonstrated a fissure at a varying distance from the cartilage surface a fact which could also be seen in radiograms. From both sides the fissure tended to be filled out with fibrous cartilage as a sign of a reparative process but blocked by a poor blood supply to the fragment. The low uptake of tetracycline and strontium 85 (Linden & Nilsson 1976) is an indication of a poor blood supply.

The articular cartilage of the lesion was normal in all respects and no thyridine-labeled chondrocytes were found i.e. no DNA synthesis and consequently no cell division. The thickness of the cartilage was normal in all preparations.

It is apparent that the sequence of events is primarily in the bone in man

and not in the cartilage as in animals (Olsson 1976). Aichroth (1971 a) has shown that unstable osteochondral fractures fail to unite. Histologically, these ununited fragments resembled OD lesions with a viable hyaline articular cartilage lying over acellular necrotic bone. On the basis of the present investigation one cannot deny that some form of trauma plays a role in the formation of OD.

This investigation showed that OD in adults seems to represent some form of subchondral fracture with intact articular cartilage. If the healing process is restricted the mobility of the fragment gives rise to cracks in the cartilage.

In treating OD, the aim must be to improve the blood supply to the lesion, i.e. to obtain connection with the medullary cavity.

REFERENCES

- Aichroth, P. (1971 a) Osteochondral fractures and their relationship to osteochondritis dissecans of the knee. *J Bone Jt Surg* 53 B 449-454.
- Aichroth, P. (1971 b) Osteochondritis dissecans of the knee. A clinical survey. *J Bone Jt Surg* 53-B 440-447.
- Axhausen, G. (1914) Die Entstehung der freien Gelenkkörper und ihre Beziehungen zur Arthritis deformans. *Arch klin Chir* 104 581-599.
- Axhausen, G. (1922) Die Ätiologie der hohlen sehen Erkrankung der Metatarsalköpfchen. *Bruns Beir klin Chir* 126 457-476.
- Chiroff, R. T. & Cooke, C. P. (1975) Osteochondritis dissecans. A histologic and microradiographic analysis of surgically excised lesions. *J Trauma* 15 689-696.
- Conway, F. W. (1937) Osteochondritis dissecans. Description of the stages of the condition and its probable traumatic etiology. *Amer J Surg* 58 691-699.
- Fairbank, H. A. T. (1933) Osteochondritis dissecans. *Brit J Surg* 21 67-82.
- Hellström, J. (1922) Beitrag zur Kenntnis der sog. Osteochondritis dissecans im Kniegelenk. *Acta chir scand* 55 190-221.
- Jaffe, H. L. (1972) Metabolic degenerative and inflammatory diseases of bones and joints.



Figure 2 The same specimens as in Figure 1. On both sides of the fissure new mesenchymal tissue has formed (Goldner $\times 25$)

sure was found in the bone located, in different specimens, at a varying distance from the overlying articular cartilage. The fissure was situated immediately under the hyaline articular cartilage in one preparation, but in another at a distance of up to 10 mm from the tide-mark in the articular cartilage (Figure 1). On both sides of the fissure, but especially in the detached fragment there were islands of necrotic bone with disorganization of the trabeculae in the form of fragmentation, but also coarse and clumsy trabeculae. Some of the lacunae were empty, but normal osteocytes could also be seen in the lacunae (Figure 2). Both osteoblastic and osteoclastic activity were observed. In preparations stained according to Goldner, an increased number of osteoid seams near the fissure could be visualized on both its sides.

In some preparations newly formed connective tissue, at various stages of differentiation, had begun to fill out the fissure. In some, this differentiation had gone so far as to be fibrous cartilage as seen with toluidine-blue staining.

Further from the fissure the bone became more normal on both sides with normal marrow and gracile trabeculae with lacunae accompanied by osteocytes. No osteoid seams could be seen here.

With fluorescent microscopy no tetracycline labeling was visible in the bony part of the osteochondritic lesion.

DISCUSSION

Osteochondritis dissecans may be defined as a partial or complete separation of a cartilage-bone fragment from a joint with the separation of the fragment from the surrounding tissue taking place gradually (Smilie 1960).

The cause of this separation being obscure, no theory is fully accepted. The hypothesis of ischemia postulates an interruption of the blood supply to an area of subchondral bone, which would then lead to sequestration of the bone together with the overlying articular cartilage (Riegman 1920, Axhausen 1922, Watson-Jones 1952). This interruption is supposed to be caused by emboli of fat, bacteria or red corpuscle aggregation.

Some form of osteonecrosis has been postulated. The osteonecrosis may appear as the result of an interrupted blood supply consequent upon traumatic squashing without fracture of the articular bone end (Roessner 1922, Jaffe 1972).

The hypothesis of trauma has been accepted by various authors, from the first investigation of König in 1887 up to the present time. The trauma can be an impact of the bone by the opposing joint surface (Axhausen 1914), rotating forces (Kappis 1920), bone impression of the

THE RADIOLUCENT ZONE IN ARTHROPLASTY OF THE KNEE

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Roentgenograms of 135 knee joint arthroplasties were examined for the prevalence and extent of a radiolucent zone at the bone-cement interface. Such a zone was significantly more common around the plastic tibial part than around the metallic femoral part of non hinged prostheses. This observation argues for the theory that the development of heat plays a part in the causation of the zone. In some cases a zone was demonstrable within 1 month of the operation. The frequency and the sizes of such zones increased during the first 6 months after the operation. There was no definite correlation between the development of a radiolucent zone and the clinical symptoms.

Key words: arthroplasty, knee joint, radiolucent zone.

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The roentgenogram after total knee arthroplasty often shows a radiolucent zone at the bone-cement interface. This zone does not exceed a few millimeters in width. It has a well-defined limit and is sometimes surrounded by a more or less pronounced sclerotic zone in the bone. It should be differentiated from the wider, more diffusely limited zone, sometimes with so-called "scalloping", typical of infection. The cause and the clinical significance of this zone are unknown. It was therefore thought worthwhile to focus special attention on the problem in association with a review of total arthroplasty of the knee at the Department of Orthopaedic Surgery, Malmö General Hospital (Ahlberg & Linden 1977).

MATERIAL AND METHODS

Roentgenograms of 138 knees treated with arthroplasty (16 Guépar, 52 Geomedic, 40 St Georg) during the period 1972-1975 were examined for a radiolucent zone around the femoral and/or tibial part and were classified into four groups according to the extent of the zone (Table 1, Figures 1 and 2). The roentgenograms were routine frontal and lateral views obtained at various intervals after the operation. As a rule the examinations were performed immediately after operation and 1, 3, 6 and 12 months post-operatively. The occurrence and extent of the zones were examined for any correlation with (a) the type and part of the prosthesis, (b) the interval after the operation, (c) the amount of cement and (d) the clinical symptoms.

Table 1. Classification of zones

0 = No zone
+ = Zone occupying less than half bone ce

++ =

+++ =
1 cm

- p 592-594, Urban & Schwarzenberg, München-Berlin
- Kappis M (1920) Osteochondritis dissecans und traumatische Gelenkmause *Dtsch Z Chir* 157, 187-213
- König, F (1887) Ueber freie Körper in den Gelenken *Dtsch Z Chir* 27, 90
- Långenskiöld, A (1955) Can osteochondritis dissecans arise as a sequel of cartilage fracture in early childhood? *Acta chir scand* 109 204-209
- Lindén C B & Nilsson, B F (1976) Strontium 85 uptake in knee joints with osteochondritis dissecans *Acta orthop scand* 47, 668-671
- Lindén, C B (1976) Longterm follow-up of osteochondritis dissecans in the femur condyles. In Osteochondritis dissecans Dissertation, University of Lund
- Olsson S F (1976) Osteochondrosis—a growing problem to dog breeders *Genes Progress* 1-11
- Rehbein, F (1950) Die Entstehung der Osteochondritis dissecans *Arch Klin Chir* 265 69-114
- Reiland, S (1975) Osteochondrosis in the pig Thesis, Stockholm
- Riegan H (1920) Zur Pathogenese von Gelenkmausen *Munch med Wschr* 67, 719-721
- Roessner, F (1922) Die Entstehungs Mechanik der sog Osteochondritis dissecans an Kniegelenk *Bruns Beitr klin Chir* 127, 537-561
- Scheller, S (1960) Roentgenographic studies on epiphyseal growth and ossification in the knee *Acta radiol (Stockh)* Suppl 195
- Schenk, R (1965) Zur histologischen Verarbeitung von unentkalkten Knochen *Acta anat (Basel)* 60 3-11
- Smillie, I S (1960) *Osteochondritis dissecans Loose bodies in joints Etiology pathology treatment* F & S Livingstone Edinburgh and London
- Tallquist, H (1962) The reaction to mechanical trauma in growing articular cartilage *Acta orthop scand* Suppl 53
- Watson Jones, R (1952) *Fractures and joint injuries* Vol I, p 97 I & S Livingstone Edinburgh and London

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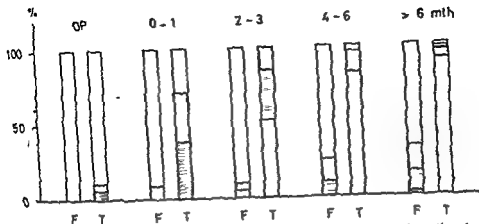


Figure 3 Radiolucent zone correlated with time after operation in Geomedic arthroplasty

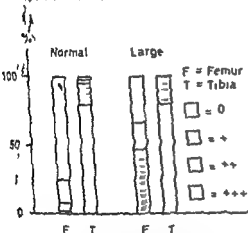


Figure 5 Radiolucent zone correlated with amount of cement in Geomedic arthroplasty

of cement was classified as large in 15 femora and 40 tibiae owing to an unnecessarily large cementing or to communication with subchondral cysts. No difference in the incidence of tibial zones was found between the two groups possibly because of the relatively high frequency of zones even in tibiae with a normal amount of cement. In femora with a large amount of cement zones were twice as common as otherwise (Figure 5). The difference however was not significant.

(d). Of the patients who had been followed up for at least 6 months, 15 reported moderate persistent pain and six severe pain. The distribution of these

cases according to the various groups of zone formation did not differ from that in the entire material.

DISCUSSION

The cause of the radiolucent zone is still obscure. Three possibilities have been discussed, viz, mechanical injury to vessels during preparation of the bed, chemical injury caused by the monomer, and thermal injury from the heat generated by polymerisation. Various model experiments favour one or the other of these theories or argue against others. Thus, Jefferiss et al (1975) contend that the heat generated is unimportant while Feith (1975) claims that it is more important than the chemical and mechanical factors. According to Linder (1977) the surgical preparation of the bed is more important than the monomer leakage.

The most significant result of the present clinical investigation was that a radiolucent zone is the rule around the tibial but the exception around the femoral part of non hinged prostheses. It is possible that part of the radiolucent zone around the femoral prosthesis remained concealed because the metal is projected over part of the bone-cement interface.



Figure 1 St Georg arthroplasty Radiolucent zone femur = - tibia = +++



Figure 2 Geomedic arthroplasty Radiolucent zone femur = 0 tibia = ++

RESULTS

(a) The occurrence and extent of the radiolucent zones relative to the type and part of the prosthesis are given in Figure 3, which is based on the last roentgenogram in each case obtained 6 months to 4 years after the operation (14 Guepar, 68 Geomedic, 40 St Georg). The number of Guepar arthroplasties was small and no significant difference was found between the femoral and the tibial parts. As for the other two types of prosthesis, radiolucent zones were almost invariably seen around the tibial part but only around one-third of the number of femoral parts. This difference is highly significant.

(b) The largest group of knees had been treated with a Geomedic prosthesis and this group was therefore used in the investigation of any variation of the incidence and extent of the radiolucent zones with the interval after the oper-

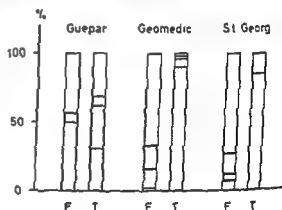


Figure 3 Radiolucent zone correlated with type and part of prostheses

ation. It is clear from Figure 4 that within 1 month a radiolucent zone was seen in two-thirds of the tibial prostheses and in one-tenth of the femoral prostheses. The incidence and extent of the tibial zones increased rapidly from one interval to the next. The corresponding increase of the femoral ones was slow.

(c) The zones were examined for any correlation with the amount of cement in the same group as (b). The amount

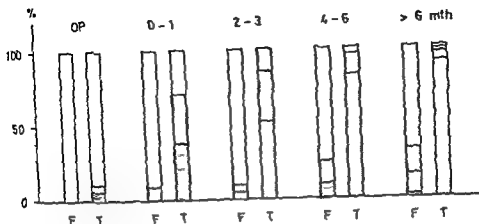


Figure 4 Radiolucency correlated with time after operation in Geomedic arthroplasty

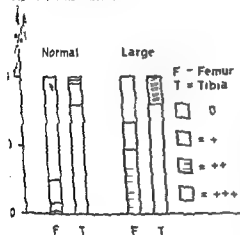


Figure 5 Radiolucency correlated with amount of cement in Geomedic arthroplasty

Cement was classified as large in 15 femora and 40 tibiae owing to an unusually large cementing or to communication with subchondral cysts. No difference in the incidence of tibial zones was found between the two groups possibly because of the relatively high frequency of zones even in tibiae with a normal amount of cement. In femora with a large amount of cement zones were twice as common as otherwise (Figure 5). The difference however was not significant. Of the patients who had been followed up for at least 6 months 15 reported moderate persistent pain and six severe pain. The distribution of these

cases according to the various groups of zone formation did not differ from that in the entire material.

DISCUSSION

The cause of the radiolucency zone is still obscure. Three possibilities have been discussed viz mechanical injury to vessels during preparation of the bed, chemical injury caused by the monomer and thermal injury from the heat generated by polymerisation. Various model experiments favour one or the other of these theories or argue against others. Thus Jefferiss et al (1975) contend that the heat generated is unimportant while Feith (1975) claims that it is more important than the chemical and mechanical factors. According to Linder (1977) the surgical preparation of the bed is more important than the monomer leakage.

The most significant result of the present clinical investigation was that a radiolucency zone is the rule around the tibial but the exception around the femoral part of non hinged prostheses. It is possible that part of the radiolucency zone around the femoral prosthesis remained concealed because the metal is projected over part of the bone cement interface.

But those parts of the bone cement interface demonstrable in the roentgenogram are sufficient to reveal any true difference between the femur and the tibia. This can hardly be explained by mechanical and vascular damage from the preparation. In both parts the preparation of the bed is the same and the cement is placed in spongy bone. Also any toxic effect of monomers should presumably be the same since Linder (1977) has shown that the cement volume is irrelevant for the monomer loss from the cement. An important difference, however, is that the tibial prosthesis is made of high density polyethylene and the femoral prosthesis of metal. The latter conducts and takes up heat more readily and this results in the effect of the heat being smaller around the femoral part of this form of prosthesis. In knee prostheses, however, both the femoral and the tibial parts are made of metal, and in these cases no difference in frequency of radiolucent zones was found between the two parts. The investigation therefore appears to suggest that the generation of heat plays a role in the development of the radiolucent zones.

In about one-tenth of the tibial parts of the Geomedic prostheses, a zone was present already in the immediate post-operative films. The same observation has been made by Insall et al (1976) in their total condylar prostheses and a probable explanation is a thin film of blood between the cement and bone. Already 1 month after the operation a zone was seen in two-thirds of our Geomedic prostheses, and this number continually increased during the first 6 months after

operation. The same observation was made by Reckling et al (1977) who believed that the reason for this was a micro-motion between bone and cement. The progression of the zone, however, might also be explained by thermal necrosis with subsequent bone absorption (Slooff 1971).

The appearance of a zone is sometimes regarded as a sign of loosening of the prosthesis. One reason for this may be that both the radiolucent zone and loosening most often are localized to the tibial part. In the present material there was no demonstrable correlation between postoperative results or persisting clinical symptoms and the occurrence of zones.

REFERENCES

- Ahlberg A & Lindén B (1977) Arthroplasty of the knee in osteoarthritis and rheumatoid arthritis. *Acta orthop scand* 48: 89-104.
- Leith R (1975) Side effects of acrylic cement implanted into bone. *Acta orthop scand* Suppl 161: 72-117.
- Insall J, Ranawat C S, Scott W N & Walker P (1976) Total condylar knee replacement. *Clin Orthop* 120: 149-154.
- Jefferiss C D, Lee, A J C & Ling R S M (1975) Thermal aspects of self curing poly methylmethacrylate. *J Bone Jt Surg* 57 B: 511-518.
- Linder I (1977) Reaction of bone to the acute chemical trauma of bone cement. *J Bone Jt Surg* 59 A: 82-87.
- Reckling F W, Asher M A & Dillon W I (1977) A longitudinal study of the radiolucent line at the bone-cement interface following total joint replacement procedures. *J Bone Jt Surg* 59 A: 335-358.
- Slooff T J J H (1971) The influence of acrylic cement. An experimental study. *Acta orthop scand* 42: 465-481.

PERFORMANCE EVALUATION OF BK AMPUTEES THROUGH GRADED LOAD CARRYING TESTS

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The ergonomic approach to performance evaluation in orthopaedic rehabilitation presents problems because of the cumbersome and time consuming measurement and test procedures involved. This paper describes a method of performance evaluation through graded load carrying tests which makes it possible to set up regression equations which can be used in routine clinical practice for prediction of the performance of below knee amputees.

Key words: performance evaluation, regression equation, ergonomic tests, biomechanical tests, energy expenditure, patellar tendon bearing prosthesis, graded load carrying, peak heart rate, resting heart rate.

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The importance of an objective evaluation of a rehabilitee's performance at the terminal stage of any rehabilitation programme cannot be overemphasized. In the case of a lower extremity handicap, the technique of such objective evaluation has so far taken two basic forms: (i) *ergonomic*, where the rehabilitee is asked to perform a few standard tasks or work activities during which energy expenditure and other associated cardio-respiratory responses are measured and (ii) *biomechanical*, where the mechanical aspects of performance such as range of motion at joints, muscular involvement, muscle power etc. are studied by mechanical, electrical or electronic means or a combination of these.

The ergonomic approach has an edge over the biomechanical approach in that it is a more comprehensive technique, came up with a series of tests for unilateral below-knee amputees using

system as a whole whereas the latter only furnishes information about one or at best a few aspects of his body mechanics. However, the main disadvantage of the ergonomic method lies in the cumbersome measurement techniques that are normally used, and besides, the number of tasks that the subject has to perform in order to generate worthwhile data makes it an exhausting time-consuming procedure unsuitable for routine clinical application. In spite of such shortcomings, the basic superiority of the ergonomic approach must not be overlooked and having realised this fact, some of the present authors have evolved a suitable test battery which can be used in routine clinical practice.

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REFERENCES

- Ahlberg A & Lindén, B (1977) Arthroplasty of the knee in osteoarthritis and rheumatoid arthritis. *Acta orthop scand* 48 III 104.
- Keith, R (1975) Side effects of acrylic cement implanted into bone. *Acta orthop scand* Suppl 161, 72-117.
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- Jefferiss, C D, Lee, A J C & Ling H S W (1975) Thermal aspects of self curing polymethylmethacrylate. *J Bone Jt Surg* 57 B 511-518.
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PERFORMANCE EVALUATION OF BK AMPUTEES THROUGH GRADED LOAD CARRYING TESTS

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B. N. ROY & K. S. BOSE

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The ergonomic approach to performance evaluation in orthopaedic rehabilitation presents problems because of the cumbersome and time consuming measurement and test procedures involved. This paper describes a method of performance evaluation through graded load carrying tests which makes it possible to set up regression equations which can be used in routine clinical practice for prediction of the performance of below knee amputees.

Key words: performance evaluation, regression equation, ergonomic tests, biomechanical tests, energy expenditure, patellar tendon bearing prosthesis, graded load carrying, peak heart rate, resting heart rate.

Accepted 20.11.77

The importance of an objective evaluation of a rehabilitate's performance at the terminal stage of any rehabilitation programme cannot be overemphasized. In the case of a lower extremity handicap the technique of such objective evaluation has so far taken two basic forms: (i) *ergonomic* where the rehabilitate is asked to perform a few standard tasks or work activities during which energy expenditure and other associated cardio-respiratory responses are measured and (ii) *biomechanical* where the mechanical aspects of performance such as range of motion at joints, muscular involvement, muscle power etc. are studied by mechanical, electrical or electronic means or a combination of these.

The ergonomic approach has an edge over the biomechanical approach in the sense that it produces information about the performance of the patient's body

system as a whole whereas the latter only furnishes information about one or at best a few aspects of his body mechanics. However, the main disadvantage of the ergonomic method lies in the cumbersome measurement techniques that are normally used and besides the number of tasks that the subject has to perform in order to generate worthwhile data makes it an exhausting time consuming procedure unsuitable for routine clinical application. In spite of such shortcomings the basic superiority of the ergonomic approach must not be overlooked and having realised this fact some of the present authors have evolved a suitable test battery which can be readily applied in the clinical setting.

Ganguli et al (1973 and 1975) in their search for such a clinically acceptable technique came up with a series of tests for unilateral below knee amputees using

Table 1 Means and standard deviations of the data of control group and test group subjects

Control group (n = 6)					
	Age (years)	Height (cm)	Body weight (kg)	Body surface area (m ²)	
Mean	31.5	163.4	51.8	1.54	
S D ±	7.4	7.7	6.7	0.13	
Test group (n = 6)					
	Age (years)	Height (cm)	Body weight with prosthesis and shoe (1 g)	Body weight without prosthesis and shoe (kg)	Body surface area (m ²)
Mean	24.2	161.2	45.65	47.47	1.41
S D ±	4.6	4.2	5.1	4.92	0.08

patellar-tendon-bearing (PTB) prostheses. The tests included four common activities of daily living and working, i.e., sitting upright in a chair, standing in the erect posture, walking on level ground at a convenient speed and ascending a staircase. Although otherwise quite pragmatic, the individual tasks and their respective energy expenditures had no definite relationship with each other, and therefore the method did not leave any scope for prediction of energy expenditure by extrapolation from regression curves, and each time evaluation of the performance of a new amputee was required it was necessary to repeat the whole test series.

This paper describes a series of tests involving a graded exercise, where it has been possible to establish a correlation between the tasks and thus set up regression equations for prediction of energy expenditure of other comparable subjects.

METHOD AND MATERIALS

The test battery included the following activities: (a) sitting upright in a chair as in a sedentary type of work, (b) walking a distance

of 1 km on level ground at the rate of 3 km/h, this activity being a very common one for daily living and working, and (c) walking on level ground with a shoulder pack with loads of 5 kg, 10 kg, 15 kg and 20 kg. The rate and distance of the walk was the same in the graded load carrying tests as in the level walking test with out any load.

These tests were administered to a test group made up of six below knee amputees using PTB prostheses and a control group of six matched normal healthy able bodied subjects. The mean and standard deviations of the data of the subjects in both the groups are given in Table 1. Figure 1 shows an amputee test subject performing the graded load carrying test.

The tests were carried out between 1000 and 1200 h in the morning and only after the whole procedure and purpose of the study had been carefully explained to the subjects on their arrival at the laboratory in a post-absorptive state. For regulation of speed and timing over the measured distance an investigator accompanied the subjects during the walks.

During each test the parameters studied were energy expenditure (kcal/min), oxygen consumption (l/min STPD), pulmonary ventilation (l/min BTPS) and peak heart rate (beats/min). Oxygen consumption and energy expenditure were determined by collecting the expired air in a Douglas Bag and subsequently analysing it in a Haldane gas analysis apparatus. The resting heart rate was recorded by timing 20 heart beats several times during the last 5 minutes of the rest period preceding the test and noting the lowest value; the peak heart rate was recorded



Figure 1 A below knee amputee fitted with a PTB prosthesis and performing the graded load carrying test

similarly starting at the moment of the cessation of activity

The energy expenditure, oxygen consumption and pulmonary ventilation values were expressed per unit body weight (kg) to eliminate differences between individuals as far as body build was concerned. For the test group the weights of the prostheses and shoes were not considered since no energy was directly consumed by the prosthetic appliances and foot wear; on the other hand the body muscles had to expend extra energy to carry these external loads.

Students *t* test was used for the various parameters to determine the differences if any between the two groups.

The investigation was carried out during winter and spring when the thermal environment was generally pleasant and mild as is evident from the following data which were collected.

Dry bulb range 21.0–28.0°C (mean 30.5°C)

Wet bulb range 12.0–28.0°C (mean 25.0°C)

RESULTS AND DISCUSSION

The means and standard deviations of the energy expenditure, oxygen consumptions, pulmonary ventilations and peak heart rates observed in the control as well as the test group subjects are presented in Table 2.

Considering the mean values of Table 2, it was observed that while the resting energy expenditure of the below-knee amputees was around 25 per cent higher than those of the control subjects, walking without any load increased this difference markedly, the amputees expending 86.7 per cent more energy than the controls. In the load carrying (5, 10, 15 and 20 kg), the below-knee amputees displayed an increase in energy expenditure of 70 per cent compared with the control group for the first three loads and 82 per cent for the heaviest load. As far as oxygen consumption was concerned, the differences between the two groups were of a similar order. The difference in pulmonary ventilation was 33 per cent at rest, 71 per cent for walking without any load and 53.8, 51.7, 56.9 and 65.7 for carrying loads of 5, 10, 15 and 20 kg respectively. As regards peak heart rate, the increments in the test group were lower, viz. 4.9 per cent at rest, 17.1 per cent for walking without any load and 16.1, 19.8, 21.2 and 22.4 per cent for walking with 5, 10, 15 and 20 kg, respectively. As expected, the values for all the parameters increased as the load became heavier in both the groups.

The relationships between energy expenditure (kcal/min/kg) and load carried (kg) as shown in Figure 2, can be expressed by the following equations

$y = 0.0322 + 0.0018x$ for the control group subjects ($r = +0.84$) and $y = 0.0535 + 0.0032x$ for the test group subjects ($r = +0.77$) where x and y are the load carried in kg and energy expenditure in kcal/min/kg, respectively. The rise in energy expenditure with load carrying

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S.D. ±	4.6	4.2	5.1	4.92	0.08

patellar-tendon-bearing (PTB) prostheses. The tests included four common activities of daily living and working, i.e., sitting upright in a chair, standing in the erect posture, walking on level ground at a convenient speed and ascending a staircase. Although otherwise quite pragmatic, the individual tasks and their respective energy expenditures had no definite relationship with each other, and therefore the method did not leave any scope for prediction of energy expenditure by extrapolation from regression curves, and each time evaluation of the performance of a new amputee was required it was necessary to repeat the whole test series.

This paper describes a series of tests involving a graded exercise, where it has been possible to establish a correlation between the tasks and thus set up regression equations for prediction of energy expenditure of other comparable subjects.

METHOD AND MATERIALS

The test battery included the following activities: (a) sitting upright in a chair as in a sedentary type of work; (b) walking a distance

of 1 km on level ground at the rate of 3.1 m/h; this activity being a very common one for daily living and working; and (c) walking on level ground with a shoulder pack with loads of 5 kg, 10 kg, 15 kg and 20 kg. The rate and distance of the walk was the same in the graded load carrying tests as in the level walking test without any load.

These tests were administered to a test group made up of six below knee amputees using PTB prostheses and a control group of six matching normal healthy able-bodied subjects. The means and standard deviations of the data of the subjects in both the groups are given in Table 1. Figure 1 shows an amputee test subject performing the graded load carrying test.

The tests were carried out between 1000 and 1200 h in the morning and only after the whole procedure and purpose of the study had been carefully explained to the subjects on their arrival at the laboratory in a post-absorptive state. For regulation of speed and timing over the measured distance an investigator accompanied the subjects during the walk.

During each test the parameters studied were: energy expenditure (kcal/min), oxygen consumption (l/min STPD), pulmonary ventilation (l/min BTPS) and peak heart rate (beats/min). Oxygen consumption and energy expenditure were determined by collecting the expired air in a Douglas Bag and subsequently analysing it in a Haldane gas analysis apparatus. The resting heart rate was recorded by timing 20 heart beats several times during the last 5 minutes of the rest period preceding the test and noting the lowest value. The peak heart rate was recorded

parameters of the control group and the test group subjects

Test group					
Rest	Walking without load	Walking with 5 kg	Walking with 10 kg	Walking with 15 kg	Walking with 20 kg
0.020	0.056	0.069	± 0.082	0.097	0.122
± 0.004	± 0.012	± 0.013	± 0.015	± 0.019	± 0.035
0.0043	0.0122	0.0148	0.0175	0.0209	0.0262
± 0.0008	± 0.0025	± 0.0028	± 0.0031	± 0.0038	± 0.0076
0.16	0.36	0.40	0.44	0.50	0.58
± 0.08	± 0.07	± 0.06	± 0.07	± 0.08	± 0.13
76.7	93.7	102.5	110.5	117.2	128.8
± 4.5	± 4.8	± 6.6	± 10.2	± 6.7	± 17.4

administer only one of the first three load carrying tests so that the test subject has only to carry 5 kg, 10 kg or 15 kg in the shoulder pack and the value of energy expenditure so obtained may be used for cross-checking the validity of the regression equation by substituting the value of the load carried and obtaining directly the energy expenditure in kcal/min/kg. This would simplify the evaluation procedure to a large extent thus making it suitable for routine clinical use. From this point of view, the method described in this paper is superior to the one earlier suggested by Ganguli et al (1973, 1975) and offers much wider scope for clinical application.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the technical staff of the Section of Physiological and Industrial Hygiene, All India Institute of Hygiene and Public Health, Calcutta, and also to the medical and paramedical staff of the Department of Orthopaedics, University College of Medicine, University of Calcutta.

REFERENCES

- Ganguli, S., Datta S R, Chatterjee, B B & Roy, M N (1973) Performance evaluation of an amputee-prosthesis system in below-knee amputees *Ergonomics* 16 797-810.
- Ganguli, S., Bose, K M & Datta, S R (1975) Performance of BK amputees using PTB prostheses *Acta orthop scand* 46 123-134.

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Table 2 Means and standard deviations of physiological

	Control group					
	Rest	Walking without load	Walking with 5 kg	Walking with 10 kg	Walking with 15 kg	Walking with 20 kg
Energy expenditure (kcal/min/kg)	0.016 ± 0.03	0.030 ± 0.008	0.040 ± 0.009	0.048 ± 0.007	0.057 ± 0.010	0.067 ± 0.012
Oxygen consumption (l/min STPD/kg)	0.0033 ± 0.0008	0.0063 ± 0.0019	0.0086 ± 0.0018	0.0102 ± 0.0015	0.0121 ± 0.0015	0.0144 ± 0.0029
Pulmonary ventilation (l/min BTPS/kg)	0.12 ± 0.03	0.21 ± 0.06	0.26 ± 0.05	0.29 ± 0.04	0.32 ± 0.05	0.35 ± 0.06
Peak heart rate (beats/min)	73.1 ± 6.4	80.0 ± 6.8	88.3 ± 9.2	92.2 ± 10.8	96.7 ± 10.2	105.2 ± 11.7

was greater in the below-knee amputees than in the test group subjects.

Interpretations based on the application of the paired *t* test for comparison between the controls and the test group subjects are as follows:

- (i) During rest, the differences between these two groups for all the parameters studied were not significant.
- (ii) For walking on the level without any load, the differences in values of all parameters, excepting oxygen consumption, were highly significant.
- (iii) For all denominations of load carrying, the differences were significant for all the parameters but were of a high order in the case of energy expenditure, oxygen consumption and pulmonary ventilation and of a low order for peak heart rate.

REGRESSION OF RATES OF ENERGY EXPENDITURE DURING LOAD CARRYING TEST

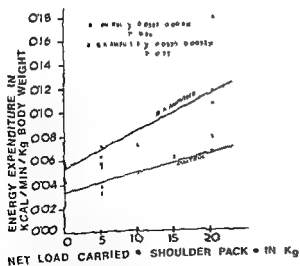


Figure 2 The relationship between energy expenditure (kcal/min/kg) and load (kg) in the control group and test group subjects

CONCLUSIONS

This investigation has shown that while the increase in the physiological effect on the below-knee amputees was much greater during level walking without any load than for load-carrying, the difference between the first three load conditions, viz., 5, 10 and 15 kg was, for all practical purposes, insignificant. Taking advantage of this finding one can safely



Figure 1 Vertical fracture of the neck of the talus without displacement (Hawkins Group I) Black arrows indicate fracture



Figure 2 Vertical fracture of the neck of the talus with displacement of the body from the subtalar joint (Hawkins Group II)

advocated by Boyd & Knight (1942) and McKeever (1963). Later studies support this view (Kenwright & Taylor 1970, Hawkins 1970).

According to Kenwright & Taylor (1970) the prognosis for displaced fractures is much better when an acceptable initial reduction has been achieved.



Figure 3 Vertical fracture of the neck of the talus with displacement of the body from both the talocrural and subtalar joints (Hawkins Group III)

Avascular necrosis is a late complication can occur in about 60 per cent of cases (Hawkins 1970). Once established the treatment varies: conservative measures have been suggested by Mindell et al (1963).

Classification

Various classifications have been put forward. The most accepted is that of Hawkins (1970) which is as follows:

- Group I Vertical fracture of the neck of the talus without displacement (Figure 1)
- Group II Vertical fracture of the neck of the talus with displacement of the body from the subtalar joint but not from the talocrural joint (Figure 2)
- Group III Vertical fracture of the neck of the talus with displacement of the body from both the subtalar and talocrural joints (Figure 3)

FRACTURE OF THE NECK OF THE TALUS

A Clinical Study

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A clinical evaluation of 46 patients treated for fractures of the neck of the talus has been made after a mean follow-up period of 3 years. The cause of injury was most frequently motor vehicle accidents (26) and falls from heights (11). In non-displaced fractures plaster with immobilization was used and displaced fractures were treated by closed or open reduction. At follow-up most of the patients complained of symptoms hampering daily activities. Objectively, excellent to good results were obtained in 75 per cent of the non-displaced fractures and in 42 per cent of the displaced. Delayed union occurred in 15 per cent. Avascular necrosis was found in 15 per cent and degenerative changes in 97 per cent. A decreased density of bone under the articular cartilage, called subchondral atrophy, was seen in 50 per cent.

Key words: fractures, talus, treatment, follow up

Accepted 8.11.77

Fractures of the talus occur in aviation and motor vehicle accidents, in falls from heights and as a result of falling objects (Anderson 1919, Miller & Baker 1939, McKeever 1963, Coltart 1952, Mindell et al 1963, Kenwright & Taylor 1970, Hawkins 1970, Sneppen & Buhl 1974). These fractures can involve the whole of the talus with comminution and displacement or the restoration of function of the limited only to the neck of the talus. In this case the fracture may be either non-displaced or displaced.

The simple fracture without displacement of the neck of the talus seldom presents any problems as regards treatment or the restoration of function of the foot. The displaced fracture, however, poses difficulties regarding the immediate treatment and may also impair the future function of the foot depending on

whether or not avascular necrosis develops.

Non-displaced fractures

The majority of these fractures are treated initially by immobilization in plaster until radiological union has been demonstrated (Miller & Baker 1939, Boyd & Knight 1942, McKeever 1963, Coltart 1952, Mindell et al 1963, Kenwright & Taylor 1970).

Avascular necrosis as a late complication has been encountered occasionally, e.g. in 2 per cent as reported by Brinkmann et al (1973). Otherwise the results are reported to be excellent to good.

Displaced fractures

Coltart (1952) suggested an accurate reduction by closed or open means for displaced fractures which also has been

FRACTURE OF THE NECK OF THE TALUS

Table 3 Type of accident causing fracture of the neck of the talus in 46 patients

Type of accident	Classification (Hawkins)			Total accidents
	I	II	III	
Motorcar driver	3	5	6	14
Motorcar passenger	2	1	1	4
Motorcycle driver	1	3	-	4
Motorcycle passenger	1	-	-	1
Pedestrian	-	2	-	2
Bicycle	-	1	-	1
Fall from a height	3	6	2	11
Athletics	2	1	1	4
Fall on object	1	3	1	5
Total	13	22	11	46

Table 5 Treatment in 46 patients with fracture of the neck of the talus

Treatment	Classification (Hawkins)			Total
	I	II	III	
Non weight bearing no immobilization	-	1	-	1
Immobilization in plaster	13	3	-	16
Closed reduction + immobilization in plaster	-	8*	6	14
Open reduction + immobilization in plaster	-	4	4	8
Open reduction + internal fixation + immobilization in plaster	-	6	1	7
Total	13	22	11	46

* percutaneous transfixation in 1 patient

joint's circumference of the lower leg and around the malleolae instability of the ankle joints

All radiographs from the primary and later examinations and clinical follow up were studied. Anteroposterior projections were taken of each ankle and lateral projections with a maximum of active plantar and dorsal flexion in order to detect subluxation of the ankle joint. All patients were examined under non weight bearing conditions and both talocrural and subtalar joints were always examined under identical conditions.

Suitable exposure data were chosen in order to be able to judge optimally the architecture of the bone trabeculae of the talus and surrounding bones. A special film with a high silver content (Kodak Industrex) was of great value for this investigation.

Possible displacement of subluxation of the

attempt was made to judge the time of healing the appearance of sclerosis and also subchondral atrophy which is a new concept based on the observation that a thin zone of lessened bone density can appear under the articular cartilage.

The articulations of the talus were judged by the following criteria

Table 4 Associated injuries in 20 out of 46 patients with fracture of the neck of the talus

Injury	Classification (Hawkins)			Total injuries
	I	II	III	
Skull	1	4	1	6
Upper extremity	2	1	-	3
Same lower extremity	4	8	6	18
Other lower extremity	4	3	-	7
Soft tissue	-	2	-	2
Total	11	18	7	36

Follow-up

All patients were contacted by letter and by telephone and 42 were traced of whom six could not be examined for various reasons. Thus 36 patients 24 men and 8 women were included in the follow up.

The period of observation varied from 1 year and 4 months to 13 years and 4 months with a mean of 6 years (Figure 5).

A questionnaire was sent to the patients and once returned the clinical examination was carried out. Questions regarding various aspects of foot function pain and gait had to be answered.

The patients were questioned especially with regard to possible change of work because of the foot injury, the need for special shoes, foot supports and walking aids. The following was registered: gait with special reference to limping, range of motion in talocrural and subtalar

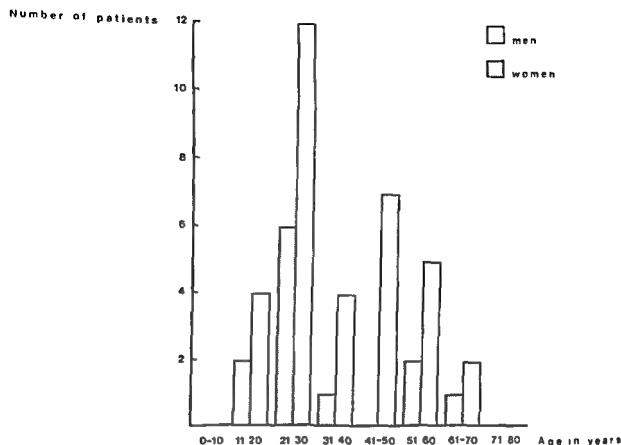


Figure 4 The distribution of age and sex at the time of injury in 46 patients with fracture of the neck of the talus

PATIENTS AND METHODS

The following clinical investigation was carried out 1) to report on a material of patients treated during the years 1960-1972 for fracture of the neck of the talus 2) to make a clinical evaluation of this material with a mean follow up time of 6 years (1 year 4 months 13 years 4 months) 3) to make a radiological assessment of late results and 4) to correlate if possible the clinical impressions with experimental observations (Peterson & Goldie 1975).

The material consisted of patients who were treated for fracture of the neck of the talus from

Table 2 Classification according to Hawkins (1970) of 46 fractures of the neck of the talus

Sex	Classification			Total
	I	II	III	
Men	9	18	7	34
Women	4	4	1	12
Total	13	22	11	46

Table 1 Cause of injury in 46 patients with fracture of the neck of the talus

Injury	Men	Women	Total
Traffic	15	11	26
Fall from a height	10	1	11
Athletics	4	0	4
Falling objects	5	1	6
Total	34	12	46

1 January 1960 until 31 December 1972. Forty six patients were collected.

The distribution of age and sex at the time of injury is shown in Figure 4.

There were four main causes of injury (Table 1): Traffic accidents, falls from heights, athletic accidents, injury from falling objects.

The classification of the fractures is seen in Table 2 and their relation to cause in Table 3.

Associated injuries are presented in Table 4. The treatment is presented in Table 5 and related to the classification.

Only two local complications were registered and these were wound infections.

Table 6 Complaints at follow-up of 36 patients in relation to the patient's general opinion of the function of the foot

Symptoms	Classification						Total	
	I		II		III		Satis- fied	Unsatis- fied
	Satis- fied	Unsatis- fied	Satis- fied	Unsatis- fied	Satis- fied	Unsatis- fied		
	4	4	8	11	5	4	17	10
Pain at rest	—	—	—	7	—	2	—	9
Pain when walking less than 2 kilometres	—	—	—	6	—	1	—	7
Pain when walking more than 2 kilometres	—	1	—	8	1	2	2	11
Not able to run normally	—	4	1	11	1	4	2	19
Pain when walking on uneven surface	—	4	5	11	2	4	7	19
Limping	—	—	1	5	—	3	1	8
Not able to do ordinary exercise	—	4	1	9	1	3	2	16
Not able to do athletics	2	4	5	11	3	4	10	19
Stiffness	—	3	1	9	1	3	2	15
Tiredness	—	—	—	4	—	2	—	6
Swelling	1	1	—	7	2	2	3	10

RESULTS AT FOLLOW UP

Symptoms experienced by patients in relation to subjective opinion of function

A relationship was established between the symptoms the patients experienced at follow up and their subjective opinion of the foot function (Table 6). It is evident from this table that most patients complained of symptoms which to some degree hampered their daily activities.

Of the 36 patients followed up three had no work, two of them being retired and one a student. Of the remaining 33 patients 26 went back to their original work after termination of the compensation period. Quite a number (15) had problems with their foot at work but not to such a degree that it was incapacitating. Four had sedentary work and had no trouble except that they experienced discomfort from their foot during free-time activities.

Seven patients had to change occupa-

tion mainly because of pain in the fractured foot.

Of the 36 patients, five needed special equipment such as Lange's foot support and heel increases.

Objective clinical examination

Limping was found in nine patients.

The bimalleolar circumference compared with the healthy side was increased by 1.3 cm in ten patients and, of these, five belonged to Group III.

The circumference of the lower leg was decreased on the injured side by 2–3 cm in seven patients. Of these, four belonged to Group III.

No atrophy of the skin was noted. One patient (Group II) had a slight varus and excavatus deformity of the fractured foot. One patient (Group III) had a rigid equinus foot (10°). In the remaining patients the foot had a normal appearance.

The range of motion is presented in Table 7.

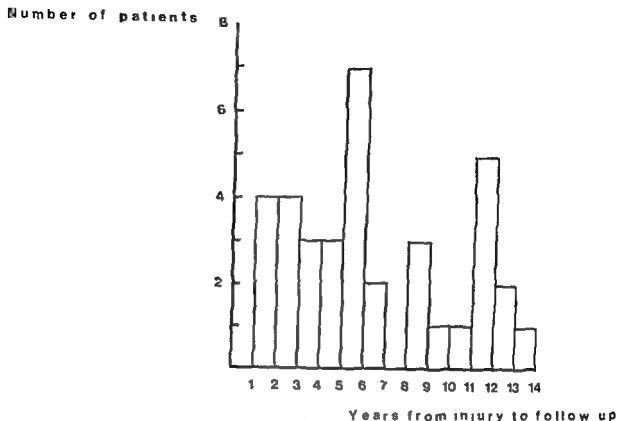


Figure 5 Period of observation at follow-up in 36 patients with fracture of the neck of the talus

- A Normal appearance
 B Osteophytes
 C Reduced joint space including osteophytes

and sclerosis. In this group the type of cases included were those where the joint was disorganized by the fracture but after healing the joint space remained normal (Figures 6a and b).

- D Ankylosis



Figure 6a Fifty year old man with Group III fracture of the neck of the talus treated with closed reduction and immobilization



Figure 6b Same as in Figure 6a. At follow-up 13 years and 4 months after injury there is reduction of the posterior subtalar joint space and osteophyte formation

Table 6 Complaints at follow-up of 36 patients in relation to the patient's general opinion of the function of the foot

Symptoms	Classification						Total	
	I		II		III		Satis- fied	Unsatis- fied
	Satis- fied	Unsatis- fied	Satis- fied	Unsatis- fied	Satis- fied	Unsatis- fied		
	4	4	8	11	5	4	17	19
Pain at rest	-	-	-	7	-	2	-	9
Pain when walking less than 2 kilometres	-	-	-	6	-	1	-	7
Pain when walking more than 2 kilometres	-	1	-	8	1	2	2	11
Not able to run normally	-	4	1	11	1	4	2	19
Pain when walking on uneven surface	-	4	5	11	2	4	7	19
Limping	-	-	1	5	-	3	1	8
Not able to do ordinary exercise	-	4	1	9	1	3	2	16
Not able to do athletics	2	4	5	11	3	4	10	19
Stiffness	-	3	1	9	1	3	2	15
Tiredness	-	-	-	4	-	2	-	6
Swelling	1	1	-	7	2	2	3	10

RESULTS AT FOLLOW UP

Symptoms experienced by patients in relation to subjective opinion of function

A relationship was established between the symptoms the patients experienced at follow up and their subjective opinion of the foot function (Table 6). It is evident from this table that most patients complained of symptoms which to some degree hampered their daily activities.

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tion mainly because of pain in the fractured foot.

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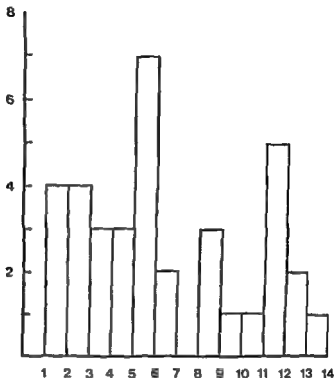
The bimalleolar circumference compared with the healthy side was increased by 1-3 cm in ten patients and, of these, five belonged to Group III.

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No atrophy of the skin was noted. One patient (Group II) had a slight varus and excavatus deformity of the fractured foot. One patient (Group III) had a rigid equinus foot (10°). In the remaining patients the foot had a normal appearance.

The range of motion is presented in Table 7.

Number of patients



Years from injury to follow up

Figure 1 Period of observation at follow up in 36 patients with fracture of the neck of the talus

- A Normal appearance
 B Osteophytes
 C Reduced joint space including osteophytes

and sclerosis. In this group the type of cases included were those where the joint was disorganized by the fracture but after healing the joint space remained normal (Figures 6a and 1).

- D Ankylosis



Figure 6a 15-year-old man with Group III fracture of the neck of the talus treated with closed reduction and immobilization



Figure 6b Same as in Figure 6a. At follow-up 13 years and 4 months after injury there is reduction of the posterior subtalar joint space and osteophyte formation

Table 2 Investigator's assessment of clinical results at follow-up of 36 patients with fracture of the neck of the talus

	Classification (Hawkins)			Total
	I	II	III	
Excellent	4	1	1	6
Good	2	5	4	11
Fair	2	8	3	10
Poor		7	2	9
Total	8	19	9	36

- Excellent = Normal range of foot motion compared with healthy side
No pain at rest and none or only minor subjective symptoms
0-2 symptoms listed in Table 7
- Good = 0-25 per cent restricted range of foot motion compared with healthy side
No pain at rest
3-5 symptoms listed in Table 7
- Fair = 26-50 per cent restricted range of foot motion compared with healthy side
6-8 symptoms listed in Table 7
- Poor = > 50 per cent restricted range of foot motion compared with healthy side
9-11 symptoms listed in Table 7



Figure 7 Fifty six year-old woman with Group II fracture treated with non weight bearing for 6 weeks. Tomogram (in lateral projection) shows non union 9 months after injury and sclerotic of the talar body

Damage of the anterior margin of the tibia. Special attention was paid to possible damage to the anterior margin of the distal tibia. Except in one case no skeletal damage was observed at the an-



Figure 8 a, b Lateral and AP views of Group II fracture of left talus 8 weeks after injury with subchondral atrophy (arrows). This atrophy cannot be seen radiologically through plaster

Table 7 Decrease in range of motion after fracture of the neck of the talus as a percentage of the range measured on the healthy side

Foot motion	Classification (Hawkins)		
	I	II	III
Dorsal flexion	17	45	31
Plantar flexion	2	10	12
Pronation/supination	12	34	33

Only one patient experienced pain when mobility was tested and this occurred in supination, which was restricted. Unloaded motion of all types was free of pain in the remaining patients.

No crepitations were felt and no instability could be registered. The investigator's assessment is shown in Tables 8 and 9.

Table 8 Investigator's assessment of range of motion at follow-up of 36 patients with fracture of the neck of the talus

	Classification (Hawkins)			Total
	I	II	III	
Excellent	4	1	1	6
Good	3	6	5	14
Fair	1	10	2	13
Poor		2	1	3
Total	8	19	9	36

Excellent	=	Normal range of foot motion compared with healthy side
Good	=	0-25 per cent restricted range of foot motion compared with healthy side
Fair	=	26-50 per cent restricted range of foot motion compared with healthy side
Poor	=	> 50 per cent restricted range of foot motion compared with healthy side

Radiologic assessment

This has been centred on evaluation of delayed union, avascular necrosis, degenerative changes, subchondral atrophy

and damage to the anterior margin of the tibia.

Delayed union Delayed union in this material was diagnosed when no healing was radiographically evident within 6 months. There was one delayed union in Group I, four in Group II and one in Group III. All these had united at the time of follow-up. Clinically these patients were free from symptoms excepting one of those in Group II who had developed avascular necrosis (Figure 7).

Avascular necrosis This developed in six patients, four women and two men. Three were in Group II, three in Group III. Their treatment included early mobilization and weight-bearing.

Degenerative changes The diagnosis of degenerative changes or osteoarthritis was based on radiographic criteria of decreased joint space, sclerosis of juxta-articular bone and osteophytes.

The number of patients with degenerative changes in relation to the classification of their injury was as follows:

Classification	I	II	III	Total
Normal appearance	1			1
Osteophytes	3	8	7	20
Reduced joint space including osteophytes and sclerosis	2	10	2	14
Anchylolysis		1		1

Subchondral atrophy During the investigation it became evident that a certain radiologic sign might have some importance in the prognostic estimation of the development of avascular necrosis. Subchondral atrophy was the term used for the demonstration on X-ray films of a thin subchondral line with decreased bone density (Figure 8). This appeared after 6-8 weeks and could either be total or partial. In 18 cases of Group II and III fracture this line of subchondral atrophy was total and in 17 no avascular necrosis developed.

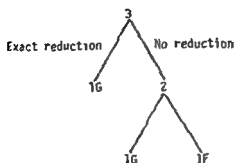
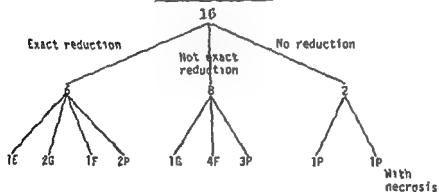
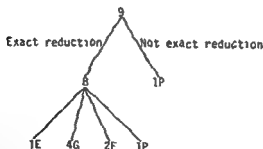
FRACTURE GROUP II WITH DISPLACEMENT ≤ 3 mmNumber of patientsFRACTURE GROUP II WITH DISPLACEMENT > 3 mmNumber of patientsFRACTURE GROUP III WITH DISPLACEMENT > 3 mmNumber of patients

Figure 3 Relation between the degree of reduction of Group II and III fractures and the results at follow-up E = Excellent G = Good F = Fair P = Poor

terior tibial margin. This gives support to the mechanism of injury of talar neck fractures suggested by Peterson et al (1976).

DISCUSSION

Fractures of the neck of the talus without displacement have a good prognosis but the occasional complication with avascular necrosis cannot be overlooked (Hawkins 1970, Kenwright & Taylor 1970, Brinkmann et al. 1973). Avascular necrosis is above all a radiologic diagnosis and need not yield any clinical symptoms. In this material there was no evidence of avascular necrosis in the Group I fractures and the clinical results were excellent or good in six out of eight cases. It appeared essential to immobilize the foot in plaster but weight-bearing seemed to have no adverse effects, provided that it was postponed until 1 month after the injury. This period of non-weight-bearing seems to follow naturally after the injury because of the discomfort caused by weight-bearing during the first month.

In previous studies the importance of a good reduction, either closed or open, of displaced fractures has been emphasized (Miller & Baker 1939, Boyd & Knight 1942, McKeever 1963, Collari 1952, Hawkins 1970). In this material it was obvious that an exact reduction was essential for a good result (Figure 9). Whether the reduction was closed or open did not appear to have any clinical significance, but of course the choice should be made with respect to the possibility of achieving an exact reduction and maintaining this.

Avascular necrosis occurred in one patient of those treated with closed reduction (11).

One patient with avascular necrosis was treated only with non-weight-bearing for 6 weeks and the result was poor.

In this investigation avascular necrosis

developed less frequently in displaced fractures which were reduced by closed means, compared with those which required open reduction. However, if open methods were chosen it seemed that avascular necrosis developed less frequently in those fractures which were fixed internally.

Out of 36 fractures, 28 were displaced. Of these, 19 belonged to Group II and three of these developed avascular necrosis. The remaining nine displaced fractures belonged to Group III and of these three developed avascular necrosis.

The reason for avascular necrosis is obscure. It has been said that at the moment of fracture the rupture of the *arteria canalis tarsi* and *arteria sinus tarsi* enhances the risk of avascular necrosis. Support for this belief has been advanced by Marek & Schein (1945) who recorded a rate of 8 per cent avascular necrosis in triple arthrodesis.

In a study of the arterial supply of the talus (Peterson et al. 1974) it was possible to demonstrate that the talus is located in the centre of a vascular network, and is mainly supplied by the *arteria canalis tarsi* and the anastomosing *arteria sinus tarsi*, by the *rami deltoidei* from the *arteria canalis tarsi* and by branches from the *arteria dorsalis pedis* entering the neck of the talus. Furthermore, the talus is supplied by small arteries in the capsules and ligaments which connect the talus with the surrounding bones. The involvement of these vessels in the fracture mechanism of the neck of the talus could be demonstrated experimentally (Peterson & Golde 1975). It was shown that in fractures without displacement the ascending branches from the *arteria canalis tarsi* were generally ruptured as well as the descending branches from the *arteria dorsalis pedis* in the fracture area. With displacement of the body of the talus from the subtalar joint the *arteria canalis tarsi* generally ruptured, which is in accordance with

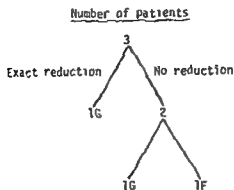
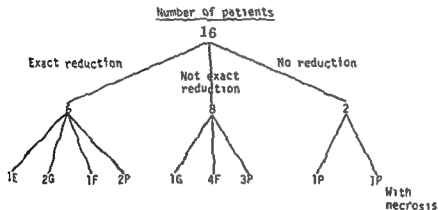
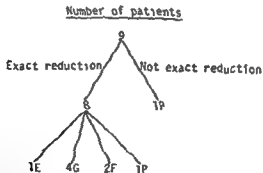
FRACTURE GROUP II WITH DISPLACEMENT < 3 mmFRACTURE GROUP II WITH DISPLACEMENT > 3 mmFRACTURE GROUP III WITH DISPLACEMENT > 3 mm

Figure 9 Relation between the degree of reduction of Group II and III fractures and the results at follow-up F = Excellent G = Good F = Fair, P = Poor

the hypothesis previously discussed by Hawkins (1970)

The clinical implication might be that the talar body can survive on the small but numerous vessels available provided that a prompt exact and stable reduction can be performed and maintained

REFERENCES

- Anderson H G (1919) *Medical and surgical aspects of aviation* Ed Browde H Oxford University Press Hodder & Stoughton London
- Bond H B & Knight R A (1942) Fracture of the astragalus *Sth med J (Bqham Ala)* 35 160 167
- Brinkmann W H Fischer H J & Jung H (1973) Diagnose und Therapie von Talusfrakturen *Bruns Beitr klin Chir* 220 194 201
- Coltart W D (1952) Aviator's astragalus *J Bone Jt Surg* 34 B 545 556
- Hawkins J G (1970) Fractures of the neck of the talus *J Bone Jt Surg* 52 A 991-1002
- Kenwright J & Taylor R G (1970) Major injuries of the talus *J Bone Jt Surg* 52 B 36 48
- Marej F M & Schein A J (1945) Aseptic necrosis of the astragalus following arthrodesing procedures of the tarsus *J Bone Jt Surg* 27 587 594
- McKeever F M (1963) Treatment of complications of fractures and dislocations of the talus *Clin Orthop* 30 45 52
- Miller O L & Balcer L D (1939) Fracture and fracture dislocation of the astragalus *Sth med J (Bqham Ala)* 32 125 136
- Windell F R Cisek I I Kartalian G & Dzib J M (1963) Late results of injuries of the talus *J Bone Jt Surg* 45 A 221-245
- Peterson I Goldie I & Lindell D (1974) The arterial supply of the talus *Acta orthop scand* 45 260-270
- Peterson L & Goldie I (1975) The arterial supply of the talus A study on the relationship to experimental talar fractures *Acta orthop scand* 46 1026 1034
- Peterson I Romanus B & Dahlberg I (1976) Fracture of the collum tali: An experimental study *J Biomechanics* 9 277 279
- Sneppen O & Buhl O (1974) Fracture of the talus *Acta orthop scand* 45 307-320

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SUBTALAR DISLOCATION

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During the period from 1945 to 1972 30 cases of subtalar dislocation were reported to the Directorate of Industrial Injuries Insurance in Denmark. The lesions were classified according to type of dislocation showing that the medial inward type predominated by far. According to the findings of the present investigation the long term prognosis seems to be more serious than has hitherto been assumed. X ray and clinical examination disclosed that arthrosis of the subtalar joints was demonstrable in 19 patients. Six of these patients had pantalar arthrosis, the causative factor in two cases being avascular necrosis of the talus. Clinical examination showed that walking was associated with some degree of pain in 21 patients and 15 patients had a more or less pronounced limp.

Key words: subtalar dislocation, subtalar arthrosis, avascular necrosis of the talus.

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Subtalar dislocation not combined with fracture of the neck of the talus is uncommon and only a few reports of the injury have appeared in the literature. The first case was reported in 1811 by Judet and Dufauress. Shands (1928) who personally had only one case of this type reviewed the cases reported before 1927 and analysed 139 cases according to type of dislocation and age and sex of the patients. Since then the studies have mainly been concerned with fractures of the talus and with the exception of a series of 27 cases reported by Kenwright & Taylor (1970) the series discussed have been numerically small (McKeever 1963, Mindell et al 1963, Pennal 1963, Thomsen 1971).

Great efforts have been devoted to the solution of the problems involved in the

treatment and prognosis of fracture and fracture dislocation of the talus, whereas the problems involved in subtalar dislocation are considered to be comparatively small. However in a series of 15 patients examined by Pennal (1963) it was found that subtalar arthrosis had developed in nine cases while Mindell et al (1963) observed two cases of avascular necrosis in a series of 10 patients. We intend with this report to elucidate the mechanism of the trauma and the prognosis of the injury.

PATIENTS AND METHODS

During the period from 1945 to 1972 30 cases of subtalar dislocation were reported to the Directorate of Industrial Injuries Insurance in Denmark where all employers are required to have their employees insured against accidents. Quite

the hypothesis previously discussed by Hawkins (1970)

The clinical implication might be that the talar body can survive on the small but numerous vessels available provided that a prompt exact and stable reduction can be performed and maintained

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- Anderson H G (1919) *Medical and surgical aspects of aviation* 1d Frowde H Oxford University Press Hodder & Stoughton London
- Bond H H & Knight R A (1942) Fracture of the astragalus *Sth med J (Bgham Ala)* 35 160 167
- Brinkmann W H Fischer H J & Jung H (1973) Diagnose und Therapie von Talusfrakturen *Bruns Beitr klin Chir* 220 194 201
- Coltart W D (1952) Aviator's astragalus *J Bone Jt Surg* 34 B 545-556
- Hawkins L G (1970) Fractures of the neck of the talus *J Bone Jt Surg* 52 A 991-1002
- Kenwright J & Taylor R G (1970) Major injuries of the talus *J Bone Jt Surg* 52 B 36-48
- Marek I M & Schein A J (1945) Aseptic necrosis of the astragalus following arthrodysing procedures of the tarsus *J Bone Jt Surg* 27 587 594
- McKeever F M (1963) Treatment of complications of fractures and dislocations of the talus *Clin Orthop* 30 45 52
- Miller O I & Baker L D (1939) Fracture and fracture dislocation of the astragalus *Sth med J (Bgham Ala)* 32 125-130
- Mindell I R Cisek F E Kartalian G & Dzoup J M (1963) Late results of injuries of the talus *J Bone Jt Surg* 45 A 221 245
- Peterson L Goldie I & Lindell B (1974) The arterial supply of the talus *Acta orthop scand* 43 260 270
- Peterson L & Goldie I (1975) The arterial supply of the talus. A study on the relationship to experimental talar fractures *Acta orthop scand* 46 1026 1034
- Peterson L Romanus B & Dahlberg F (1976) Fracture of the collum tali: An experimental study *J Biomechanics* 9 277 279
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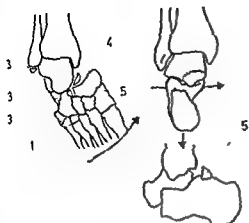


Figure 2 Type and number of associated fractures in 26 cases of medial subtalar dislocation. The mechanism is illustrated



Figure 3 Type and number of associated fractures in four cases of lateral subtalar dislocation

minor subluxations persisted. Both patients had medial dislocation and walked with the foot in supination.

Instability. One patient with medial dislocation complained of a tendency to twist the ankle in supination.

Avascular necrosis of the talus. Avascular necrosis occurred in two cases. In one case there was a temporary increase in density, but healing was complete. In the other, an increase in density and partial collapse of the body of the talus subsequently healed. The dislocations were both of the medial type: in one involving fracture of the posterior process of the talus and avulsion from the lateral malleolus, and in the other being associated



Figure 4 Medial subtalar dislocation with a typical fracture in the lateral part of the navicular bone

with fracture of the internal edge of the head of the talus and avulsion from the outer malleolus.

Arthrosis. Subtalar arthrosis was radiologically verified in 19 patients. Six of these also had talocrural arthrosis. In two of these cases the reason was avascular necrosis of the talus as mentioned above. Three of the patients had compound lesions with skin necrosis, superficial infection and a long immobilization period. Furthermore, one of them had a fracture in the lateral process of the talus. This latter patient had an ipsilateral compound tibial fracture which was repaired with a plate. Due to infection and prolonged healing, he was not allowed weight bearing until 23 weeks after the trauma. Subtalar arthrosis developed in all patients with fractures involving the subtalar joints. It was remarkable, however, that subtalar arthrosis was present in 6 patients out of 13 in whom fractures had not occurred.

Subjective symptoms. Pain in connection with walking and a limp were the predominant symptoms at follow-up. Atrophy and swelling of the calf were also seen. Nine patients had no complaints even with strenuous activities. 16 patients had moderate complaints which were most pronounced when they were



Figure 1 Medial subtalar dislocation

naturally, a series of this type is predominated by male subjects since housewives who are not employed outside the home are not insured. Thus the series comprises 29 men and one woman, averaging 39 years of age (range 15-63 years). The mechanism of injury in the 30 cases is shown in Table 1.

Table 1 Mechanism of injury in 30 subtalar dislocations

Mechanism of injury	No. of cases
Fall from a height	14
Weight falling on foot	8
Twisted ankle	5
Traffic accident	3
Total	30

The individual claims had to be settled within 1-2 years. They were assessed on the basis of supplementary data provided by the referring practitioner and the final declarations submitted by a surgeon and a radiologist. The case records applying to the subjects concerned, together with the radiographs, form the basis of the present study. The period of follow up calculated from the time of trauma to the submission of the surgical opinion covered 23 months on the average (range 9-73 months).

Treatment

Most of the dislocations were easily reduced and the joints were immobilized in a below knee plaster for 8 weeks on average (range 3-23 weeks, immobilization period unknown in four cases). Open reduction was required in two cases: in one because of buttonholing of the capsule, in the other because of spiking of the lateral corner of the navicular bone into the upper medial part of the head of the talus.

Initial complications

Nine of the 30 patients had sustained compound injuries, usually associated with considerable skin lesion over the prominent malleolus (Figure 1) through which the malleolus or head of the talus protruded. Skin necrosis was seen in three patients, in one of the latter skin grafting was required.

Deep infection was not seen primarily, in one patient it occurred after the performance of a pantalar fusion.

Classification

Dislocation of the subtalar joints involved the talo calcaneo navicular joints, i.e. subtalar or peritalar dislocation. The dislocation can be medial or lateral. The distribution is seen in Table 2.

Table 2 Type of dislocation in 30 subtalar dislocations

Type of dislocation	No. of cases
Subtalar medial dislocation	
without fractures	12
with fractures	14
Subtalar lateral dislocation	
without fractures	1
with fractures	3
Total	30

Medial dislocation is most common (Figure 1) and often results in two types of dislocation fractures: (1) fracture either of the lateral part of the navicular bone or of the upper medial edge of the head of the talus or both and (2) fracture of the posterior process of the talus. The mechanism is illustrated in Figure 2.

RESULTS

The late complications were as follows:
Postural deformation. In two cases

throsis. The injury seems to have been more severe in the group of patients with arthrosis as compound injuries were seen in four patients, in two combined with wound infection. By comparison there were only two compound injuries in the group of patients without arthrosis. A comparison of the periods of immobilization is not conclusive, but no patients with arthrosis were immobilized for less than 11 weeks, this being the general treatment in the group without arthrosis. Especially McKeever (1963) stresses the fact that early mobilization will prevent fibrosis and stiffness in the subtalar joints.

REFERENCES

- Coltart W. H. (1952) Aviators astralgus *J Bone Jt Surg* 34 B, 545-566.
- Dufauress, Percy (1811) *Journ de Corvisart* 22 348.
- Halliburton R. A., Sullivan, C. R., Kelly, P. J. & Petterson, L. P. A. (1958) The extra-osseous blood supply of the talus *J Bone Jt Surg* 40 A, 1115-1120.
- Judev, Percy (1811) *Bull Fac Med* 11, 111.
- Kenwright, J. & Taylor, R. G. (1970) Major injuries of the talus *J Bone Jt Surg* 52 B, 36.
- McKeever, F. M. (1963) Treatment of complications of fractures and dislocations of the talus *Clin Orthop* 30, 45.
- Mindell, E. R., Cisek, H. E., Kartalian H. & Dziob, J. M. (1963) Late results of injuries to the talus *J Bone Jt Surg* 45 A, 221.
- Mulfinger, G. L. & Trueta, J. (1970) The blood supply of the talus *J Bone Jt Surg* 52-B, 160-167.
- Pennal, G. F. (1963) Fractures of the talus *Clin Orthop* 30, 53.
- Petterson L., Goldie, I. & Lindell, H. (1974) The arterial supply of the talus *Acta orthop scand* 45 260-270.
- Shands, A. R. (1928) The incidence of subastralgoid dislocation of foot with report of one case of inward type *J Bone Jt Surg* 10, 306-313.
- Thomassen E. (1943) Luxatio pedis subtalo *Acta chir scand* 88 115-131.
- Watson Jones, R. (1962) *Fractures and Joint Injuries* Livingstone London.

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walking over uneven ground, nine of these patients had a slight limp. Five patients had severe complaints, their activity was greatly restricted and a limp persisted. A total of 21 patients complained of some pain in connection with walking and 14 patients had a limp.

Eighteen of the patients were engaged in heavy work. Thirteen of the 30 patients were able to resume their previous work; with certain modifications, the same applied to another eight patients, four patients had to change their work and five patients had not yet resumed work at the time when the claim was finally settled, on an average, 23 months after injury.

Subtalar arthrodesis was performed on two patients and pantalar arthrodesis on two. Deep infection occurred in one of the latter and the leg had to be amputated. Two patients had to wear ankle-braces.

DISCUSSION

The prognosis of subtalar dislocation seems to be more serious than has hitherto been assumed, primarily owing to the development of arthrosis. In agreement with findings previously reported, medial dislocation was the lesion most frequently encountered in the present investigation. The typical dislocation-fractures of the navicular bone and the medial edge of the head of the talus are mentioned by Watson-Jones (1962), but fractures of the posterior process of the talus have not attracted much attention. The posterior talo calcaneal joint comprises the basal surface of the posterior tubercle that is facing plantar laterally. This explains why fracture will occur if the calcaneum is forced medially as this will cause avulsion of the tubercle. The mechanism seems obvious and, accordingly, medial distortion of the subtalar joints should be suspected in the presence of a fracture.



Figure 5. Medial subtalar dislocation with typical fracture of the posterior process of the talus. Avulsion of the tubercle by the dislocated calcaneum.

The incidence of vascular necrosis rather surprising, however, Mindell et al. (1963) observed the phenomenon in two out of 10 patients. Studies of the blood supply to the talus (Haliburton et al. 1958, Mulfinger & Trueta 1970, Pettersen et al. 1974) indicate that the body of the talus is supplied mainly by the tarsal canal artery. The latter may be damaged by the dislocation and, in the presence of fracture of the posterior tubercle, as seen in one of our patients in whom necrosis occurred, the vascularization will suffer additionally.

Posteriorly, a network is formed by branches from the posterior tibial artery and the peroneal artery. Branches which run to the posterior process arise from this network, finally to enter into the bone.

From clinical experience it is known that arthrosis easily develops if fractures involve the joints. Thus the high incidence of arthrosis after subtalar dislocation not combined with fracture is remarkable. Six patients out of 13 without fractures in the subtalar joints had ar-

throsis. The injury seems to have been more severe in the group of patients with arthrosis as compound injuries were seen in four patients in two combined with wound infection. By comparison there were only two compound injuries in the group of patients without arthrosis. A comparison of the periods of immobilization is not conclusive but no patients with arthrosis were immobilized for less than 8 weeks, this being the general treatment in the group without arthrosis. Especially McKeever (1963) stresses the fact that early mobilization will prevent fibrosis and stiffness in the subtalar joints.

- Haliburton R A, Sullivan C R, Kelly P J & Petterson L P A (1958) The extra-osseous blood supply of the talus. *J Bone Jt Surg* 40 A 1115-1120.
- Judey Percy (1811) *Bull Fac Med* 11 81.
- Kenwright J & Taylor R H (1970) Major injuries of the talus. *J Bone Jt Surg* 52 B 36.
- McKeever F W (1963) Treatment of complications of fractures and dislocations of the talus. *Clin Orthop* 30 45.
- Mundell E R, Cisek M E, Kartalian G & Dzib J M (1963) Late results of injuries to the talus. *J Bone Jt Surg* 45 A 221.
- Mullinger G L & Trueta, J (1970) The blood supply of the talus. *J Bone Jt Surg* 52 B 160-167.
- Pennal G F (1963) Fractures of the talus. *Clin Orthop* 30 53.
- Petterson L, Goldie I & Lundell D (1974) The arterial supply of the talus. *Acta orthop scand* 45 260-270.
- Shands A R (1928) The incidence of subastragaloid dislocation of foot with report of one case of inward type. *J Bone Jt Surg* 10 306-313.
- Thomassen E (1913) Luxatio pedis subtalo. *Acta chir scand* 115-131.
- Watson Jones R (1963) Fractures and joint injuries. Livingstone, London.

REFERENCES

- Celtart W D (1952) Aviators astralgus. *J Bone Jt Surg* 34 B 545-566.
- Dufauvent Percy (1811) *Journ de Corvisart* 22 348.

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TREATMENT OF CHRONIC HAEMATOGENOUS OSTEOMYELITIS OF THE OS CALCIS

ABULFOTOOH M EID

Twenty five patients suffering from chronic haematogenous osteomyelitis of the os calcis were studied. The disease often presents in a subacute or chronic form and the pathological process is well established in the majority of the cases by the time treatment is begun. For this reason conservative treatment was found to be ineffective. Similarly limited surgical procedures such as curettage, sequestrectomy or partial excision were also inadequate because of the wide spread nature of the infection. Complete excision of the os calcis and stitching of the Achilles tendon to the plantar fascia was followed by a high rate of success provided the other tarsal bones were not involved in the infective process. The infection was cured and reasonably normal function was obtained in 14 out of 19 patients (73.7 per cent). A new heel is often formed after the operation by the laying down of plaques of calcification within the toughened scar tissue of the heel pad.

Key words: osteomyelitis of calcis

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Chronic haematogenous osteomyelitis of the os calcis is often difficult to treat (Martini et al 1974). Conservative treatment, partial excision of the os calcis and calcaneotomy have been tried by different authors with varying and often conflicting results, with amputation not infrequently being the outcome (Mackay & Mines 1958).

The aim of this study was to analyse and compare the effect of the different types of treatment mentioned above.

PATIENTS

This series consisted of 25 patients: 17 males (68.0 per cent) and 8 females (32.0 per cent). Their ages ranged from 6 to 32 years with an average of 17.9. Radiographically the whole of the os calcis was involved in 11 patients (44.0 per cent), whereas in six (24.0 per cent) the affection was only partial (less than one third

of the os calcis). The greater part of the os calcis (more than one third of the bone but not its entire bulk) was involved in eight patients (32.0 per cent). Other foci of osteomyelitis were encountered in eight patients and in six of them other tarsal bones were involved.

The duration of the disease before the commencement of treatment varied from 1 week to 11 years.

METHODS OF TREATMENT

All the patients were treated conservatively for periods varying from 3-32 weeks. This involved antibiotic therapy, supportive treatment and immobilisation when necessary. Patients not responding favourably to the above regime were treated surgically.

Thirteen patients with only partial and rarely extensive involvement of the os calcis underwent conservative surgery: curettage in eight, excision of the affected segment in seven and sequestrectomy in three. Five of these patients had more than one surgical procedure each.

In 19 patients the os calcis was excised com-

Table 1 The various lines of treatment applied and their results, related to the age at the time of treatment, the extent of involvement of the os calcis and the duration of the disease prior to treatment

Number	Age (years)	I tinent	Other tarsal bones affected	Conservative treatment				Conservative surgery			Excision of the os calcis		
				Sinuses	Duration (months)	Follow up (months)	Result	Duration (months)	Follow-up (months)	Result	Duration (months)	Follow-up (months)	Result
1	13.5	E	—	3	3	16	poor	19	11	poor	30	110	good
2	10	W	yes	1	11	22	poor				33	107	good
3	6.5	P	—	—	1/4	108	good						
4	7	E	—	2	4	17	poor	21	105	good			
5	17	E	—	1	5	32	poor	37	11	poor	43	105	good
6	27	W	—	1	61	8	poor	69	10	poor	79	92	good
7	23	W	—	3	14	6	poor	20	12	poor	32	87	poor
8	31	W	—	1	110	5	poor	115	9	poor	124	81	fair
9	9	E	—	—	1/3	88	good						
10	17	F	—	2	13	14	poor	27	7	poor	34	80	good
11	8	W	—	—	1	9	poor	10	9	fair	19	80	good
12	24.5	E	yes	—	39	7	poor	46	10	poor	56	77	poor
13	25	W	yes	1	30	9	poor	39	11	poor	50	73	good
14	8.5	P	—	—	1/4	71	fair						
15	21	W	yes	—	11	13	poor	24	5	poor	29	69	poor
16	16.5	P	—	1	5	7	poor	12	11	poor	23	65	good
17	11	P	—	—	1	9	poor	10	61	good			
18	6	P	—	—	1/2	58	good						
19	18	W	yes	1	17	13	poor				30	49	good
20	32	E	—	2	132	15	poor				147	34	fair
21	29	E	—	1	96	11	poor				107	29	good
22	20	W	yes	—	19	12	poor				31	31	poor
23	14	E	—	2	10	13	poor				23	19	good
24	13	W	—	—	14	11	poor				25	11	good
25	31	E	—	—	120	17	poor				137	8	poor

Abbreviations for extent of infective process P = partial involvement, E = extensive involvement, W = total involvement of the os calcis

pletely together with the infected soft tissues and sinuses. Eleven of these patients (57.9 per cent) had previously undergone some type of conservative surgery. The split heel incision (Gaenslen 1931) was used in all the cases and the tendo Achilles was stitched to the plantar aponeurosis. The resulting cavity was packed with sterile gauze soaked in acriflavine. Half of the pack was removed after 48 hours and the remaining part 72 hours after the operation. Post-operative immobilisation in a below knee plaster-of-Paris cast was maintained for 4-6 weeks with the ankle in about 10° equinus.

Surgical treatment was supplemented by suitable antibiotic therapy for 2-3 weeks.

Follow-up

The follow-up period was calculated from the time the particular line of treatment was applied until the final check up if treatment was successful, or in the event of treatment failure, until another line of treatment was instituted (Table 1). This period varied from 5-108 months after conservative treatment, 5-105 months after conservative surgery and 8-110 months after calcaneotomy.

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Accepted 19 June 77

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				Sinuses	Duration (months)	Follow up (months)	Result	Duration (months)	Follow up (months)	Result	Duration (months)	Follow up (months)	Result
1	13½	E	—	3	3	16	poor	11	11	poor	30	110	good
2	19	W	yes	1	11	22	poor				11	107	good
3	8½	P	—		1¼	108	good						
4	7	P	—	2	4	17	poor	21	105	good			
5	17	F	—	1	5	32	poor	37	11	poor	48	105	good
6	27	W	—	1	61	8	poor	11	10	poor	79	92	good
7	23	W	—	3	14	6	poor	20	12	poor	81	87	poor
8	31	W	—	1	110	5	poor	115	9	poor	124	11	fair
9	9	P	—	—	1/3	88	good						
10	17	F	—	2	13	14	poor	27	7	poor	34	80	good
11	8	W	—	—	1	9	poor	10	9	fair	19	80	good
12	24½	E	yes	—	39	7	poor	46	10	poor	56	77	poor
13	2½	W	yes	1	30	9	poor	39	11	poor	50	73	good
14	8½	P	—		1¼	71	fair						
15	21	W	yes	—	11	13	poor	24	5	poor	29	69	poor
16	16½	P	—	1	5	7	poor	12	11	poor	23	65	good
17	11	P	—	—	1	9	poor	10	61	good			
18	6	P	—		1/2	58	good						
19	18	W	yes	1	17	13	poor				30	49	good
20	32	F	—	2	132	15	poor				147	34	fair
21	29	E	—	1	96	11	poor				107	29	good
22	20	W	yes	—	19	12	poor				31	24	poor
23	14	E	—	2	10	13	poor				23	19	good
24	13	W	—		14	11	poor				25	11	good
25	31	F	—		120	17	poor				137	8	poor

Abbreviations for extent of infective process P = partial involvement F = extensive involvement W = total involvement of the os calcis

pletely together with the infected soft tissues and sinuses Eleven of these patients (57·9 per cent) had previously undergone some type of conservative surgery The split heel incision (Caenslen 1931) was used in all the cases and the tendo Achilles was stitched to the plantar aponeurosis The resulting cavity was packed with sterile gauze soaked in acriflavine Half of the pack was removed after 48 hours and the remaining part 72 hours after the operation Post-operative immobilisation in a below knee plaster of Paris cast was maintained for 4-6 weeks with the ankle in about 10° equinus

Surgical treatment was supplemented by suitable antibiotic therapy for 2-3 weeks.

Follow-up

The follow up period was calculated from the time the particular line of treatment was applied until the final check up if treatment was successful or in the event of treatment failure until another line of treatment was instituted (Table 1) This period varied from 5-108 months after conservative treatment 5-105 months after conservative surgery and 8-110 months after calcaneotomy

RESULTS

In assessing the results, each important factor was given a number out of 100, viz

A) Healing of sinuses	25
B) Functional performance	35
a) Movements of the ankle and subtalar joints, both active and passive	7
b) Ability to stand on tiptoe	7
c) Ability to stand on the heel	7
d) Capacity for walking and standing	7
e) Gait, whether the patient is limping or not	7
C) The opinion of the patient	30
a) Pain	15
b) Shape of the heel	5
c) Functional capacity at work	10
D) Footwear	10
Total	100

Results were assessed as follows. Good if the patient scored 75 or more, fair if he scored 50-75 and poor if he scored less than 50.

Results obtained are shown in Table 1. In patients who received proper management early in the disease process, conservative treatment yielded good results especially in younger patients. However, it can be seen from Table 2 that the best results were obtained after total excision of the os calcis.

Table 2 (Comparison of the results of the different lines of treatment applied)

Result	Conservative treatment (23)	Conservative surgery (13)	Excision of the os calcis (19)
Good	3 (12.0%)	2 (15.4%)	12 (63.2%)
Fair	1 (4.0%)	1 (7.7%)	2 (10.5%)
Poor	21 (84.0%)	10 (76.9%)	5 (26.3%)

DISCUSSION

Antibiotics may effect a cure of haematogenous osteomyelitis only if the proper therapy is started very early in the disease process (Marsha 1964). The four patients (16.0 per cent) who responded favourably to this regime had had the disease for only a short time prior to treatment. Osteomyelitis of the os calcis, however, often presents subacutely (Antonou & Conner 1974, Eid & Deif 1977), thus delaying diagnosis and treatment. By then the value of antibiotics alone is doubtful because of the resulting ischaemia and sclerosis (Buchman 1956, Trueta 1953). The os calcis, in addition, seems to be more vulnerable to blood deprivation than other bones. It derives its blood supply from the peroneal and posterior tibial vessels via two nutrient branches (Last 1966). Its plantar surface is related to poorly vascularised fibrofatty tissue, its medial and lateral surfaces are subcutaneous and its superior surface is articular. Additional blood supply analogous to the periosteal blood vessels in other bones would be very small if any. This may explain the frequency with which total and extensive involvement of the os calcis was encountered. In 4 out of 19 patients (21 per cent) who underwent calcaneotomy, the os calcis was found loose in a pool of pus (Figure 1) without blood supply. Obviously antibiotics alone could not be expected to be of help in such circumstances.

Conservative surgery in the form of curettage, sequestrectomy and partial excision of the os calcis has been recommended by some authors. The aim was eradication of the infection and the preservation of more or less normal anatomy. Results, however, were disappointing as only two patients had good results (15.4 per cent). In a third patient, the result was rated fair, but he consented to a calcaneotomy because of a persistent sinus.

healthy bone was negligible in most of the patients

Total excision of the os calcis, together with all infected soft tissues and sinuses on the other hand was followed by a high rate of success. Results were good in 63.2 per cent, fair in 10.5 per cent and poor in 26.3 per cent. The procedure complies with the essential principle of treatment of chronic bone infection, i.e. the removal *en masse* of all infected tissues. It is justified by the indolent nature of the lesion and its accompanying ischaemia: the total or extensive involvement of the os calcis in the majority of the cases, the ill defined nature of the lesion and the poor results obtained after less radical measures. The surgical approach used in this series was the midline posterior one described by Gaenslen (1931). It was found more convenient than the lateral approach advocated by Wiltse

Figure 1 The os calcis found completely loose in pool of pus with no periosteal attachment

This made a failure rate of 84.6 per cent. Curettage was tried in eight patients without improvement. As a line of treatment of chronic bone infection this has been condemned by many authors (Merz & Duthie 1964). It fails to eradicate all pockets of infection, exposes new bone to infection and leaves behind a rigid walled uncollapsible cavity which becomes readily infected. *Sequestrectomy* was tried in three patients, two of them having previously had curettage. A fair result was obtained in one patient who underwent calcaneotomy later because of a persistent sinus. *Partial excision* of the os calcis was performed in 7 patients, three of them had had curettage. Only two patients (28.6 per cent) achieved a good result. The line of excision was arbitrarily based on preoperative radiographic appearances, which did not coincide with the actual extent of the infection in the majority of the cases. In many instances the line of resection had to be advanced more than once when the cut surface showed definite evidence of infection. In addition the whole or most of the os calcis was involved in the majority of the cases (76.0 per cent of the series). Consequently the amount of



Figure 2 The deeply seated plantar scar after Gaenslen's approach



Figure 3 Spotty calcification after calcaneectomy

et al (1959) or the modified posterior approach recommended by Marlini et al (1974) Gaenslen's approach yields a deeply seated scar so that the plantar tissues form two thick cushions well adapted to weight-bearing (Figure 2), without appreciable pain. In addition, it allows access to the other tarsal bones when this is necessary.

Following successful calcaneectomy, there often occurs spotty calcification in the heel pad. This varies in extent and may amount to only small scattered plaques (Figure 3). These calcified plaques, together with the thickened and toughened scar tissue form a firm pad under the talus, thus providing a "new heel" (Figure 4). Compared with the normal side the "new heel" was shorter and broader, but the difference was slight. The height of the heel was reduced on the average by 8 mm, while its

breadth was increased by 6 mm. Only four patients (21.1 per cent) required a heel raise of 15–2 cm. Passive ankle movements showed increased dorsiflexion of an average of 65° compared with the healthy side. This may be due to lengthening of the tendo Achilles. This resulted in slight weakness of tip-toeing, which, however, did not materially affect the gait of these patients. Only three patients complained of easy fatiguability after walking. Eversion and inversion after calcaneectomy were practically the same as on the normal side. Conversely, all movements were restricted following partial excision of the os calcis, possibly due to muscle spasm consequent upon persistent infection. The shape of the heel and the ability to wear normal shoes were improved after calcaneectomy. In three female patients the operative scar was repaired for cosmetic reasons. This minor surgical procedure gave a greatly improved result (Figure 5).



Figure 4 A well-formed new heel



Figure 5 Improved shape of the heel after plastic repair of the scar

Because of the lack of involucrum formation in the majority of the cases (Gaenslen 1931) delaying of the operation is not recommended. Perseverence with conservative treatment will not prevent further bone destruction. It is therefore justifiable to excise the os calcis once chronic infection is established.

There were five cases of total excision (26.3 per cent) with subsequent poor results. All had persistent sinuses, pain and difficulty in wearing shoes. Four of these patients had associated osteomyelitis of other tarsal bones. The latter were not removed and thus maintained the infection. Amputation has been considered the best treatment for this situation if not controlled by conservative means

(Martini et al 1974). In the fifth case failure was caused by the leaving behind of a small part of the anterior end of the os calcis which was sufficient to maintain the infection.

REFERENCES

- Antoniou H & Conner A V (1974) Osteomyelitis of the calcaneus and talus. *J Bone Jt Surg* 56 A 338-345.
- Buchman J (1966) A survey of progress in the understanding of osteomyelitis. *Bull Hosp Jt Dis* (N.Y.) 18 60-85.
- Eid A M & Deif A (1977) Haematogenous osteomyelitis of the os calcis. A clinical study. *Egypt orthop J* (In press).
- Gaenslen F J (1931) Split heel approach in osteomyelitis of the os calcis. *J Bone Jt Surg* 11 759-772.
- Harsha W V (1964) The natural history of acute haematogenous osteomyelitis. *Sth med J (Bgham Ala)* 57 310-374.
- Last J (1966) *Anatomy Regional and applied* p 259. Churchill Ltd London.
- Mackay C R & Maues I S (1958) Osteomyelitis of the os calcis following triple arthrodesis. *Amer J Surg* 96 708-710.
- Martini M, Marthini Benkeddache Y, Bekhechi T & Daoud T (1974) Treatment of chronic
- Me
- London
- Trueta J (1953) Acute haematogenous osteomyelitis: its pathology and treatment. *Bull Hosp Jt Dis* (N.Y.) 14 5-23.
- Wiltse L L, Bateman J H & Kase, S (1959) Resection of the major portion of the calcaneus. *Clin Orthop* 12 271-278.

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